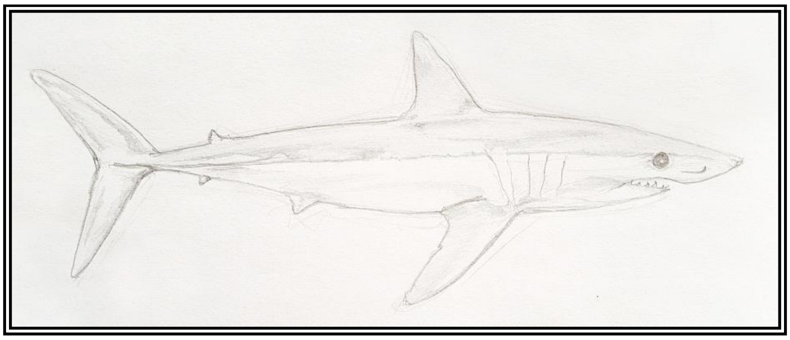
Integrating Biological and Social Information to Inform Responsible Practices for Recreational Shark Fishing

Robert P. French

B. Mar. Biol. (Hons)

Institute of Marine and Antarctic Sciences (IMAS)



Submitted in fulfilment of the requirements for the Doctor of Philosophy

April, 2017

University of Tasmania

STATEMENTS AND DECLARATIONS

Declaration of Originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

Authority of Access

This thesis may be made available for loan and limited copying and communication in accordance with the Copyright Act 1968.

Statement regarding published work contained in thesis

The publishers of the paper comprising Chapter 2 hold the copyright for that content, and access to the material should be sought from the journal. The remaining non published content of the thesis may be made available for loan and limited copying and communication in accordance with the Copyright Act 1968.

Statement of Ethical Conduct

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University. This work was carried out in accordance with University of Tasmania’s animal ethics committee approval (no. A0012230) and human ethics committee approval (no: H0013984). Access to threatened and migratory species was granted under an Australian Commonwealth Research Permit (AU-COM2013-231).

Signed

Robert French

Date 21/02/2017

Statement of Co-Authorship

The following people and institutions contributed to the publication of work undertaken as part of this thesis:

Robert P. French, Fisheries and Aquaculture Centre, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia

Dr. Jayson M. Semmens, Fisheries and Aquaculture Centre, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia

Dr. Jeremy Lyle, Fisheries and Aquaculture Centre, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia

Dr. Sean Tracey, Fisheries and Aquaculture Centre, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia

Dr. Suzanne Currie, Department of Biology, Mount Allison University, Sackville, New Brunswick, Canada

Author details and their roles:

Paper 1, High survivorship after catch-and-release fishing suggests physiological resilience in the endothermic shortfin mako shark (Isurus oxyrinchus)

Reproduced in Chapter 2; is published in Conservation Physiology - Oxford University Press:

French RP, Lyle J, Tracey S, Currie S, Semmens JM (2015) High survivorship after catch-and-release fishing suggests physiological resilience in the endothermic shortfin mako shark (Isurus oxyrinchus). Conservation Physiology 3: cov044.

The candidate was the primary author who collected and analysed the data and wrote the manuscript (55%); Jayson Semmens is the primary supervisor, providing funding, framing the concept and manuscript editing (15 %). Jeremy Lyle assisted in concept direction and manuscript editing (10%), Sean Tracey provided statistical assistance and advice on manuscript editing (5%) and Suzanne Currie (15%) provided funding, manuscript editing, laboratory access and training on blood based analyses.

We the undersigned agree with the above stated “proportion of work undertaken” for each of the above published (or submitted) peer-reviewed manuscripts contributing to this thesis:

Signed:

Associate Professor Jayson Semmens	*Professor Chris Carter*
Primary Supervisor	*Head of Centre*
Fisheries and Aquaculture Centre,	Fisheries and Aquaculture Centre,
IMAS, University of Tasmania	IMAS, University of Tasmania
Date: 01/04/2017	Date:

ACKNOWLEDGEMENTS

Foremost, I would like to thank my supervisors for their support throughout this PhD, their continued feedback and advice has been invaluable throughout the journey. In particular I would like to thank my primary supervisor Dr. Jayson Semmens for his efforts in securing funding for this project, his guidance and in particular the initial opportunity to participate in this project. My sincere thanks must also be extended to Dr Jeremy Lyle for the considerable amount time and effort that he spent guiding me through this project and the attention to detail he has put into revising my work. I am also extremely grateful to Dr Suzanne Currie for the expertise and guidance she has provided regarding stress physiology and the amazing opportunity she bestowed on me to work in her lab and meet some amazing people in Canada. Finally, a huge thank you to Dr Sean Tracey for all the time and patience you gave when guiding me through my statistical analyses, I would have been very lost without your input.

I would also like to acknowledge the huge number of people that have made this thesis possible. John Stevens volunteered much of his time to advise me when I was trying to find my feet, and for this I am very appreciative. I would also like to thank Sarah Pyke, Andrew Pender, Keno Ferter and Jaime McAllister for their continued support in the field, without their continual, committed and substantial assistance, collecting biological data would not have been possible. Additionally, the support and advice provided by Natalie Donaher, Dave Barnett, Jim Kieffer, Emily Corey, Melanie Gallant and Sacha LeBlanc in the laboratory was essential to the analysis of these data. Thank you to Klaas Hartmann for the time you took to advise me on statistical analysis. I would also like to thank the recreational anglers and volunteer researchers who took the time to assist with fieldwork and in some cases, kindly providing accommodation and hospitality: Josh Cox, Nobby Clark, Justin Drysdale, Daniel Vallance, Jonah Yick, Dave Faloon, Mike Porteus, Jason Beard, Johnny Keane, Travis Baulch, Dave Jarvis, Brett Cleary, Dennis & Kerry Heinicke, Jason, Ryan and Lucas Ivory, Denis, Greg Barea, Robyn and Rob Lucardie, Al and Rachel McGlashan, Roddy Findlay and Jaime Ward. Special thanks to Paul Rogers for project advice and field support, to Phil Bolton for his assistance with NSW field operations and networking and to Barry Bruce for organising and involving me in the mako shark workshop that took place in Hobart. Additionally I would like to thank Charlie Huveneers and Matt Heard for their cooperation during questionnaire development. I would also like to extend my gratitude to all of the game fishing clubs and organisations that assisted with the distribution of the social sciences questionnaire. Thank you to my partner Shari Armstrong for supporting me through this endeavour and supplying the lovely cover art on the title page.

This work was supported by the Department of Primary Industries, Parks, Water and Environment - Fishwise Community Grant, Equity Trustees and ANZ Trustees - Holsworth Wildlife Research Endowment and the Natural Sciences and Engineering Research Council of Canada, for which I am very appreciative.

DEDICATION

This dissertation is dedicated to my parents Les and Kath, and to my sister Natalie, who have continually supported me throughout this journey. I hope that the completion of this work will make them proud.

General Abstract

It is generally accepted that commercial fishing is capable of adversely impacting many of the world's fish stocks. However, with widespread participation and advances in technology available to anglers modern recreational fishing is now capable of matching and even exceeding the impacts of commercial fisheries. Given that sharks are a popular target for recreational fishers around the world, the expansion of recreational fishing means that this activity poses a growing threat to shark populations. Many shark species are particularly vulnerable to overfishing due to their life history characteristics (long lived, slow growth, late to mature and low fecundity) and most populations for which data exist are in decline. As such there is need to better understand and mitigate the effects of recreational fishing on sharks.

Catch-and-release is commonly promoted by fisheries managers and recreational fishers as a strategy to reduce the impact of recreational fishing on fish populations while maintaining fishing opportunities. However, post-release mortality and sub-lethal effects on growth and fitness can reduce the effectiveness of catch-and-release. Despite this, catch-and-release is often promoted with limited knowledge of how the target animals are affected or whether the practice will be adopted by the broader recreational fishing community. The long-term sustainability of recreational fisheries depends on management of both the biological resource and its human users. As such, understanding current attitudes and behaviours associated with recreational shark fishing and how sharks respond to capture and release in terms of physiology, injury and survival is critical to any future management efforts.

The shortfin mako shark (*Isurus oxyrinchus*) is a species commonly targeted by recreational anglers in many parts of the developed world. After a controversial political debate in Australia, only recreational anglers are currently permitted to target the species, contingent on the assumption that most are released and populations remain minimally impacted. The present study used the recreational fishery for shortfin mako shark as a case study of responsible recreational shark fishing due to the socio-political climate surrounding this species, its popularity as a game-fishing target and its dynamic ecological and physiological attributes. The thesis focused on three areas: (1) post-release survival and physiological stress response to capture of recreationally caught shortfin mako; (2) catch-and-release participation and the factors that may influence this behaviour; and (3) how gear choices and fishing behaviours relate to angler beliefs on sharks, their fishing impacts and their support for management. The study was based across three south-eastern Australian states; Tasmania, Victoria and New South Wales with the overall aim of integrating physiological and human dimensions research to inform and promote responsible fishing behaviour.

Using satellite tags and blood based physiological analyses, it was found that fight times did elicit a physiological response to capture, characterised by increased plasma lactate with longer fight times; however the shortfin mako was resilient to these effects and all individuals that were angled in excess of 30 minutes survived. Subsequently, following a range of short and long fight times, the shortfin mako had a high (90%) overall rate of survival after release.

Mortalities that did occur appeared to be linked to physical injuries caused by hooking, rather than physiological perturbations. The study provided evidence that circle hooks could reduce the chance of these injuries occurring.

The human element of recreational fisheries was investigated by utilising an online questionnaire directed towards fishers who had caught, or targeted mako sharks in the previous year. Survey respondents reported releasing approximately 70% of shortfin mako sharks that they had caught in the 12 months prior to the survey, although release rates were found to vary based on the state of residence. Differences in catch-and-release participation can be attributed to the varying values that individual respondents placed on shortfin mako as a sport fish and/or table fish, the opportunity for resource substitution (alternative target species) and the established norms driven by current catch-and-release practices in each state. Although members of game fishing clubs were found to be more specialised than non-members, there were no differences between these groups in the practice of catch-and-release fishing. Many anglers use J hooks when intending to retain or release sharks despite positive perceptions with regard to how circle hooks can reduce the incidence of deep hooking and hence post-release mortality. Anglers generally did not accept, or were unaware of any negative impacts of recreational fishing on the status of the mako population. Logically, widespread adoption of responsible fishing behaviours will not occur if there is a failure by anglers to acknowledge and take responsibility for the impacts of their fishing and as such, some fishers did not see a need to modify their behaviours. This perception was particularly evident when commercial fisheries are perceived to have such a comparatively large impact. Overall differences in anglers' gear use and attitudes surrounding fisheries and fisheries management were found to be most significantly related to their state of residence, suggesting that any management or education initiatives need to take these differences into account.

The uptake and utilisation of responsible fishing behaviours by the recreational fishing community is essential to the future sustainability of recreational fishing around the globe. For shark fishing, advice is provided in the form of best practices, on how to minimise physiological stress and physical injury, and reduce impacts on the environment, shark populations and bycatch. Recommendations on humanely slaughtering sharks are also discussed. Shark conservation efforts, including the adoption of responsible fishing practices can be hindered by a range of practical and attitudinal impediments that may be managed by improved education and outreach efforts. However, there is a need for more focus to be placed on effectively delivering this information to such a diverse group of resource users.

Contemporary resource management requires fisheries to be treated as complex and adaptive social-ecological systems and in achieving this there is a growing need for interdisciplinary research. This thesis has examined both the fish and the fisher to paint a holistic picture of modern shark recreational fisheries and provide valuable information which can be used in the formation of responsible fishing practices.

Table of Contents

List of Figures

List of Tables

Chapter 1
General Introduction

Recreational fishing is an activity that has existed for centuries, and the aims and satisfactions of fishers are thought to be much the same now as they have been historically (Policansky, 2002). Participation in recreational fishing has grown consistently since its early inception, in fact, the number of recreational fishers across the world today could almost double the entire global population at time of the earliest literature on recreational fishing (circa 1450) (McEvEdy and Jones, 1978; Policansky, 2002; Arlinghaus *et al.*, 2016). This dramatic expansion of effort, alongside advances in technology available to anglers (e.g.: GPS, sonar, internet and modern gears) has enabled recreational fisheries to contribute substantially to global declines in fish stocks (McPhee *et al.*, 2002; Post *et al.*, 2002; Cooke and Cowx, 2004; Cooke and Cowx, 2006; Lewin *et al.*, 2006). It is thought that recreational fishing accounts for approximately 12% of the global fishing harvest (Cooke and Cowx, 2004) and evidence exists to show that in some areas recreational harvest can exceed commercial harvest (McPhee *et al.*, 2002; Schroeder and Love, 2002; Coleman *et al.*, 2004; Cooke and Cowx, 2006; Lowther and Liddel, 2014; Shiffman, 2014) and lead to fisheries collapses (Post *et al.*, 2002). Considerable research has been focused on the impacts of commercial fishing and although it is now acknowledged that recreational fishing imposes a significant impact on global fish stocks, the recreational sector has been somewhat under-prioritised by governments and researchers, and consequently under-studied (McPhee *et al.*, 2002; Post *et al.*, 2002; Cooke and Cowx, 2004; Cooke and Cowx, 2006; Lewin *et al.*, 2006; Gallagher *et al.*, 2016; Arlinghaus *et al.*, 2017).

Given sharks are a popular target for recreational fishers, the expansion of recreational fishing means that this activity poses a growing threat to shark populations (Gallagher *et al.*, 2016). Commercial hook and line fisheries and recreational fisheries expose sharks to similar capture impacts in one form or another including hooking, struggle and handling (Cooke and Cowx, 2006), however unlike commercial fisheries, recreational fisheries are typically open access, meaning there is no limit to the number of anglers participating at any one time (McPhee *et al.*, 2002). In relation to U.S. shark fisheries, data from 2013 shows that the total recreational harvest of sharks (4.5 million pounds) exceeded commercial landings (3 million pounds) (Lowther and Liddel, 2014; Shiffman, 2014). Compounding this growing fishing pressure, many species of sharks themselves are vulnerable to overfishing due to their K-selected life history characteristics; long lived, slow growth, late to mature and low fecundity (Stevens *et al.*, 2000). On a global scale, the overall combined harvest of sharks is now believed to exceed the average rebound potential of many species and as a result most populations for which data exist are in decline (Worm *et al.*, 2013). As such, due to declining populations, low rebound potential and growing fishing pressure, there is an urgent need to better understand and mitigate the impacts of recreational fisheries on shark populations (Gallagher *et al.*, 2016).

Catch-and-release fishing is one method commonly promoted by fisheries managers as a means to maintain the availability of recreational fishing opportunities whilst reducing harvest (Arlinghaus *et al.*, 2007a). The practice involves the live release of fish back to the waters from which they were captured and may be practised due to fisheries regulations or voluntary participation by anglers (Policansky, 2002; Arlinghaus *et al.*, 2007a). While the premise of catch-and-release may seem like a simple solution to reducing the impact of fishing, there are some key factors that can reduce its effectiveness; particularly participation rate, post-release survival and effects on growth and fitness (Policansky, 2002; Arlinghaus *et al.*, 2007a; Cooke *et al.*, 2013).

Using catch-and-release to successfully reduce fishing mortality relies on the premise that after release fish will survive and contribute to the growth of the population (Bartholomew and Bohnsack, 2005; Arlinghaus *et al.*, 2007a; Wilson *et al.*, 2014). However, if individuals die after release or if growth and fitness of these animals is negatively affected the perceived benefits of catch-and-release can be ineffective (Bartholomew and Bohnsack, 2005; Arlinghaus *et al.*, 2007a). Mortality varies considerably between species and can range from near zero to almost 100% (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Morgan and Burgess, 2007). Post-release mortality can occur for a number of reasons; the two most prominent being as a result of injuries sustained from hooking and physiological perturbations that exceed the animals coping mechanisms (Muoneke and Childress, 1994; Kieffer, 2000; Skomal, 2007; Burns and Froeschke, 2012). Deep hooking is characterised by hook penetration of sensitive tissues beyond the mouth cavity such as the oesophagus, gills and organs (Fobert *et al.*, 2009) and is the most commonly attributed cause of post-release mortality in sharks (Campana *et al.*, 2009; Cooke *et al.*, 2012; Epperly *et al.*, 2012; Kneebone *et al.*, 2013). Circle hooks have been found to reduce deep hooking and hence post-release mortality in a number of sharks (Campana *et al.*, 2009; Afonso *et al.*, 2011; Kneebone *et al.*, 2013; Danylchuk *et al.*, 2014).

The negative effects of long capture durations, air exposure and handling have also been documented as impairing survival in a number of shark species (Moyes *et al.*, 2006; Frick *et al.*, 2010b; Heberer *et al.*, 2010; Kneebone *et al.*, 2013; Danylchuk *et al.*, 2014; Gallagher *et al.*, 2014). Beyond mortality, sub-lethal effects on swim function, behaviour, immune function, growth and reproduction can impact stressed individuals, although research on many of these relationships is still in its infancy (Wilson *et al.*, 2014). Due to the variability in mortality rates and stress responses between species there is a particular need for biological and physiological research to evaluate these effects on vulnerable species. Research evaluating the effect that different gears, capture techniques and environmental conditions can have on injury and stress physiology can contribute greatly to the creation of best-practice fishing methods that help to mitigate the impacts of fishing.

Early social research into recreational fisheries was largely descriptive; focusing on deriving catch and effort information, determining basic motivations for fishing, satisfactions from the experience and preference for management options (Moeller and Engelken, 1972; Knopf *et al.*, 1973; Dawson and Wilkins, 1981; Hunt *et al.*, 2013). This approach later evolved into the pursuit of understanding the diversity of attitudes and behaviours within fisher populations by attempting to segment different types of fishers using concepts such as specialisation theory and consumptive orientation (Ditton *et al.*, 1992; Fisher, 1997; Salz *et al.*, 2001; Sutton, 2001; Sutton and Ditton, 2001; Sutton, 2003). Specialisation theory comprises of a number of sub-dimensions that relate to an angler's experience, avidity, skill level and the centrality of fishing to the angler's lifestyle (Ditton *et al.*, 1992; Salz *et al.*, 2001), whereas consumptive orientation measures the importance of certain catch related variables to the angler (Fedler and Ditton, 1986; Anderson *et al.*, 2007; Kyle *et al.*, 2007). More recently, there has also been focus on the conservation ethic of recreational fishers and how this affects angling behaviours (Wallmo and Gentner, 2008; Gallagher *et al.*, 2015).

Human dimensions research is increasingly acknowledged as a fundamental component of effective fisheries management (Granek *et al.*, 2008; Hunt *et al.*, 2013; Arlinghaus *et al.*, 2016; Arlinghaus *et al.*, 2017). Ever since recreational fishers have been acknowledged as stakeholders of fisheries resources (Decker *et al.*, 1996) it has been posited that effectively managing recreational fisheries depends on understanding and cooperating with the human users of the resource, particularly as policies may be rejected if angler satisfactions are not met (Fisher, 1997; Nielsen, 1999; Kaplan and McCay, 2004). Despite the potential negative impacts of recreational fishing (e.g.: bycatch, fisheries-induced selection, trophic changes, habitat degradation, population declines (Cooke and Cowx, 2006)), recreational fishers constitute a unique and diverse group that have the potential to assume stewardship roles and promote conservation efforts that positively influence the fisheries that they are a part of (Granek *et al.*, 2008).

Despite the growing interest in understanding recreational fishers and their behaviours, few contemporary studies refer to the existing body of human dimensions research (Fenichel *et al.*, 2013). There is however, a growing call for the integration of human dimensions information with ecological, biological and physiological information so that fisheries may be managed more effectively as dynamic social-ecological systems (Hunt *et al.*, 2013; Arlinghaus *et al.*, 2016; Arlinghaus *et al.*, 2017). This concept also translates directly to the evaluation of fisheries sustainability which should be considered as a process of adaption and adjustment of fishing pressure to appropriate levels in the face of varying social-ecological pressures, as opposed to a simple measure of abundance (Hilborn *et al.*, 2015). In response to growing concern over the impact that recreational fishing may have on the long-term sustainability of global fisheries through over-exploitation and ecosystem damage the Food and Agriculture Organization of the United Nations (FAO) has created a document containing technical guidelines for responsible recreational fishing which applies to a range of stakeholders from recreational fishers to managers and researchers (FAO, 2012). It is recommended that these responsible fishing guidelines are used to assist with the direction of future management as they encompass a multidisciplinary and cooperative approach to sustainable fisheries (Arlinghaus *et al.*, 2016)

Sharks play important roles in food webs and ecosystem dynamics and the impacts of overfishing are evident in population depletions worldwide (Myers *et al.*, 2007; Bornatowski *et al.*, 2014). The shortfin mako, *Isurus oxyrinchus*, is a large pelagic shark found throughout all the worlds tropical and temperate oceans (Stevens, 2008). Like a number of other lamnids, it is characterised by a suite of morphological and physiological adaptations, including endothermy, that facilitate its high performance behaviours such as high swim speed and surface breaching (Bernal *et al.*, 2001). These behaviours make the species a popular target for recreational fishers while it is also a large component of bycatch in longline fisheries targeting tuna and billfish (Stevens, 1992, 2008). Like many elasmobranchs, the shortfin mako shark is vulnerable to fishing pressure on account of its life-history characteristics (Stevens *et al.*, 2000; Stevens, 2008). There has been considerable debate surrounding age validation of the species over the last three decades, primarily centred around whether annual or biannual band pairs are deposited on the vertebrae (Barreto *et al.*, 2016). Most recent evidence supports the theory of an ontogenetic shift in growth rate and related band pair formation, with two band pairs formed each year up until approximately five years of age, when growth slows and a single band pair is deposited thereafter (Wells *et al.*, 2013; Kinney *et al.*, 2016). This approximates longevity at 16 and 19 years of age for males and females respectively with males maturing much earlier and at much smaller sizes (180 cm FL) than females (280 cm FL); although this may vary regionally to some degree (Mollet *et al.*, 2000; Francis and Duffy, 2005; Semba *et al.*, 2011; Barreto *et al.*, 2016). Females have a three year reproductive cycle with litter sizes as small as four pups and increasing up to as many as 25 pups in the largest sharks (Mollet *et al.*, 2000). As fecundity increases with size, there is a risk that recreational fishers targeting the largest individuals for trophies will impact populations disproportionately (Shiffman *et al.*, 2014).

Declines in shortfin mako shark populations have been reported across the Atlantic Ocean (Kiyota and Nakano, 2000; Baum *et al.*, 2003) and the Mediterranean Sea (Ferretti *et al.*, 2008), with the species now considered critically endangered in the later region by The International Union for Conservation of Nature (IUCN) (Cailliet *et al.*, 2009; Bruce, 2014). Various ecological risk assessments have ranked mako as among the most vulnerable pelagic sharks for Atlantic and Australian longline fisheries (AFMA, 2009; Cortés *et al.*, 2010; Arrizabalaga *et al.*, 2011) and shortfin mako has been ranked as the most vulnerable pelagic shark species in the Indian Ocean (Murua *et al.*, 2012). As a result, the species is listed by IUCN as vulnerable globally (Cailliet *et al.*, 2009). The species is highly migratory (listed by the Convention on the Conservation of Migratory Species of Wild Animals (CMS)); however, tagging studies indicate that cross equatorial migrations of this species are exceptionally rare (Rogers *et al.*, 2015).

No stock assessments have been carried out for shortfin mako in the south west Pacific (Bruce, 2014) and despite a number of studies that have been conducted examining catch trends in this region, it is difficult to draw conclusions about abundance trends due to variable catch rates and poor performance of fisheries models used to standardise longline data (Clarke *et al.*, 2011). Evidence exists suggesting that New Zealand populations have increased since declines were noted in the late 1990's and early 2000's and these stocks may be linked to those in Australia (Francis *et al.*, 2014). Similar fluctuations in CPUE have been noted over comparable time frames in the Atlantic and were subsequently attributed to reflecting spatial variations in abundance rather than overall population trends (Skomal *et al.*, 2008). Chang and Liu (2009) reported that populations in the NW Pacific may be over-exploited. The status of remaining Pacific populations, particularly those in the southern hemisphere remain uncertain.

Despite this uncertainty, following the IUCN and CMS listings, the shortfin mako shark was listed as a protected species in Australia in 2010, under the Environment Protection and Biodiversity Conservation (EPBC) Act; making it an offence to target, catch, kill or injure this species in Australian Commonwealth waters (Bruce, 2014; Rogers and Bailleul, 2015). This listing was petitioned against by the recreational fishing sector and subsequently amendments were made to the EPBC Act that allowed shortfin mako sharks to be targeted by recreational anglers only, under the assumption that most of the sharks are released and that populations remain minimally impacted by the fishery (Bruce, 2014; Rogers and Bailleul, 2015).

Commercial takes of shortfin mako are managed and regulated by the Australian Fisheries Management Authority (AFMA). The estimated weight of all captured and retained species is recorded in logbooks by commercial operators, while the actual weights of catch unloaded at port are also recorded in the form of Catch Disposal Records (CDRs). For sharks these reported weights are based on the trunked weight of the animal. The Eastern Tuna and Billfish Fishery (ETBF) takes the largest catch of shortfin mako compared to all other commercial fisheries operating in Australian Commonwealth waters with ETBF logbook data reporting an average of 56.8t of shortfin mako retained per year from 2002 to 2014 (AFMA, 2016c), whereas ETBF CDRs report an average of 51.6t landed per year between 2007 and 2014 (AFMA, 2016b). Using the equation presented in Bruce (2014) (Live weight = trunked weight * 1.538) this equates to an estimated live weight of 87.4t and 79.4t for logbook reports and CDRs respectively. Furthermore, data analysed in Bruce (2014) suggests that under-reporting may mean that the actual catch of shortfin mako in the ETBF could have been as high as an average of 183-189t live weight per year from 2003-2010.

Tracey *et al.* (2013b) estimated the recreational catch of shortfin mako for Tasmania alone to be around 21.5 t (95% CI: 11.2 – 35.4 t) based on a survey of 467 Tasmanian private boat owners over a12 month period (November 2011 – October 2012). For the sake of scale, the Tasmanian Game Fishing Association (TGFA) reports having around 600 members enlisted across their four affiliated game fishing clubs, the Game Fishing Association of Victoria (GFAV) reports over 700 enlisted members over their 16 affiliated clubs and although the New South Wales Game Fishing Association (NSWGFA) do not disclose their overall membership numbers, just two of their 23 clubs, the Sydney Game Fishing Club (SGFC) and the Newcastle and Port Stephens Game Fishing Club (NPSGFC) report having around 400 and 450 members respectively (TGFA, 2013; SGFC, 2014; GFAV, 2016; NPSGFC, 2016; NSWGFA, 2016). Assuming that not all game fishers target sharks, if one in two game fishers retain only one mako shark per year, based on the average shark harvest weight of 68 kg (Tracey *et al.*, 2013b), this places the annual harvest at around 73 t for 1075 of the 2150 known game fishing club members, roughly equal with the reported commercial catch. This figure does not take into account members of the other 21 NSWGFA affiliated clubs or anglers that have no affiliation with fishing clubs. Furthermore, fishers that do not possess any fishing club membership comprise the majority of Australian fishers (Henry and Lyle, 2003; Tracey *et al.*, 2013b; Heard *et al.*, 2016). Although, it may be unrealistic to assume that every second game fisher will retain one mako shark each year, this scenario assists in demonstrating that recreational catches remain unreported and that combined recreational catches certainly have the potential to match and even exceed the annual commercial harvest of shortfin mako (Bruce, 2014).

Objectives and Thesis Outline

The objective of this thesis is to use an interdisciplinary research approach to improve our broad understanding of recreational shark fisheries, examine these fisheries as complex social-ecological systems, and ultimately provide information that can be used to inform responsible shark fishing practices. In order to do this, Chapter 1 (General Introduction) introduces the background and rationale to the study; it identifies the significance of recreational fishing to global fish stocks, the particular vulnerability of sharks to overfishing, issues surrounding current practices and the need to integrate human dimensions information into fisheries research and management. This chapter also highlights the unique political climate surrounding shortfin mako sharks in Australia, their popularity as a game fishing target and the biological and physiological characteristics that make this species an ideal candidate for this case study. The three subsequent data chapters focus specifically on post-release survival and stress physiology of recreationally caught mako sharks (Chapter 2), catch-and-release participation and the factors that may influence this behaviour (Chapter 3) and how gear choices and fishing behaviours relate to angler beliefs on sharks, their fishing impacts and their support for management (Chapter 4). This information is then integrated in the general discussion (Chapter 5) to provide an overall assessment of knowledge gained from these chapters and how they impact our understanding of responsible recreational fishing of sharks in the wider global context.

Shortfin mako sharks are commonly subjected to lengthy angling events; however, their endothermic physiology may provide an advantage over ectothermic fishes when recovering from exercise. The effectiveness of catch-and-release fishing as a conservation tool is contingent on the survival of released sharks and this may vary considerably between capture events. Chapter 2 assessed the post-release survival of recreationally caught shortfin mako sharks using Survivorship Pop-up Archival Transmitting (sPAT) tags and examined physiological indicators of capture stress from blood samples, as well as any injuries that may have been caused by hook selection. This chapter provides insight into how the survival of released sharks can be influenced by physiological stress, physical injuries and the high metabolic rate and aerobic scope associated with this species' thermal strategy.

It is important to understand what motivates anglers to practise catch-and-release and how often they do so, as this information can assist resource managers in identifying current impacts on fish stocks and how these impacts could be reduced through the effective promotion of catch-and-release fishing. Chapter 3 utilised a targeted online survey to examine fishing behaviour in relation to angler specialisation, consumptive orientation and motivations for catching, keeping and releasing shortfin mako sharks. These attributes are compared across the fishing club membership (club members vs non-members) and the residence (state; Victoria (Vic), Tasmania (Tas) or New South Wales (NSW)) of anglers in an effort to identify existing angling cultures and identify where educational efforts may be most effectively applied.

In catch-and-release fisheries decreased animal welfare and post-release mortality can be linked to physical injuries associated with the gear used and the handling of the animal. However, very little is documented about the specific gears and methods that recreational anglers use to target sharks and little is known concerning the rationale behind these choices. Chapter 4 examines the gear choices and fishing preferences of Australian shortfin mako shark anglers and relates these to the angler's perceptions on the impacts of shark fishing, their opinions on sharks and shark populations, and their support for fisheries management in an effort to better understand the rationale behind the practices and choices that anglers make regarding their fishing behaviours.

These three research chapters combined illustrate how biological, physiological and human dimensions data can be used to paint a holistic picture of modern shark recreational fisheries and provide valuable information which can be used in the formation of responsible fishing practices for recreational shark fishing. The uptake and utilisation of responsible fishing behaviours by the recreational fishing community is essential to the future sustainability of recreational fishing around the globe.

Chapter 2
High Survivorship after Catch-and-Release Fishing Suggests Physiological Resilience in the Endothermic Shortfin Mako Shark (Isurus oxyrinchus)

French RP, Lyle J, Tracey S, Currie S, Semmens JM (2015) High survivorship after catch-and-release fishing suggests physiological resilience in the endothermic shortfin mako shark (Isurus oxyrinchus). Conservation Physiology 3: cov044.

The shortfin mako shark (*Isurus oxyrinchus*) is a species commonly targeted by commercial and recreational anglers in many parts of the developed world. In Australia the species is targeted by recreational anglers only, under the assumption that most of the sharks are released and populations remain minimally impacted. If released sharks do not survive, the current management strategy will need to be revised. Shortfin mako sharks are commonly subjected to lengthy angling events; however, their endothermic physiology may provide an advantage over ectothermic fishes when recovering from exercise. This study assessed the post-release survival of recreationally caught shortfin mako sharks using Survivorship Pop-up Archival Transmitting (sPAT) tags and examined physiological indicators of capture stress from blood samples as well as any injuries that may be caused by hook selection. Survival estimates were based on 30 shortfin mako sharks captured off the south-eastern coast of Australia. Three mortalities were observed over the duration of the study yielding an overall survival rate of 90%. All mortalities occurred in sharks angled for less than 30 minutes. Sharks experienced increasing plasma lactate with longer fight times and higher sea surface temperatures (SSTs), increased plasma glucose at higher SSTs and depressed expression of heat shock protein 70 (HSP70) and β-hydroxybutyrate (β-OHB) at higher SSTs. Long fight times did not impact survival. Circle hooks significantly reduced foul hooking compared to J hooks. Under the conditions of this study I found that physical injury associated with hook choice likely contributed to an increased likelihood of mortality, whereas the high aerobic scope associated with the species' endothermy likely enabled it to cope with long fight times and the associated physiological responses to capture.

Introduction

Recreational fishing is a popular pastime in many parts of the developed world (Post *et al.*, 2002) and while the negative impacts of fishing on global populations has typically been attributed to commercial fisheries, it is becoming more commonly accepted that the recreational sector also contributes to many of these impacts (Mc Phee *et al.*, 2002; Post *et al.*, 2002; Coleman *et al.*, 2004; Cooke and Cowx, 2004; Arlinghaus *et al.*, 2005; Lewin *et al.*, 2006). For decades, catch-and-release fishing methods have been advocated by fisheries managers and recreational fishing organisations in an attempt to promote the sustainable use of fisheries resources (Policansky, 2002; Arlinghaus *et al.*, 2007a). However, it is recognised that not all individuals are likely to survive once released, with post-release survival rates being highly variable among species (Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Skomal and Mandelman, 2012; Gallagher *et al.*, 2014). This highlights the need to assess post-release survival on a species-by-species basis.

Like many elasmobranchs, the shortfin mako shark (*Isurus oxyrinchus*) is vulnerable to fishing pressure due to its life history characteristics (Hoenig and Gruber, 1990; Stevens, 2008; Semba *et al.*, 2011). It is an endothermic species with one of the highest metabolic rates recorded for any pelagic shark; this implies a high aerobic scope that could be an advantage when dealing with physiological disturbances (Sepulveda *et al.*, 2007). The shortfin mako shark is a popular target species for game fishers and a substantial portion of the bycatch in commercial longline fisheries targeting tuna and billfish (Stevens, 2008). In Australia, the shortfin mako shark was listed as a protected species under the Environment Protection and Biodiversity Conservation (EPBC) Act in 2010, following listings by the International Union for Conservation of Nature (IUCN) and Convention on the Conservation of Migratory Species (CMS), as 'vulnerable' and 'migratory' respectively. A controversial political debate around the protection of the species in Australia resulted in the shortfin mako shark remaining available to be targeted by recreational anglers only, under the assumption that most of the sharks are released and that populations remain minimally impacted by the fishery. There is, however, little information on post-release survival rates for recreationally caught shortfin mako sharks, and thus uncertainty as to the efficacy of the current management strategy.

In many instances angling mortality can be linked to physical injuries associated with the gear used and the handling of the animal (Muoneke and Childress, 1994; Cooke and Hogle, 2000; Cooke and Suski, 2004; Bartholomew and Bohnsack, 2005; Campana *et al.*, 2009; Carruthers *et al.*, 2009; Burns and Froeschke, 2012). Capture related physiological disruptions exceeding a fish's ability to return to homeostasis can also result in mortality of released individuals (Kieffer, 2000; Moyes *et al.*, 2006; Hight *et al.*, 2007; Frick *et al.*, 2010a; Frick *et al.*, 2012). Additionally, physiological disruptions can influence the behaviour of released fish, resulting in increased vulnerability to predation during the recovery period (Brownscombe *et al.*, 2014; Raby *et al.*, 2014).

Physiological responses to stressors can be observed through changes in blood chemistry and it has been observed that the magnitude of the stress response in sharks and other fishes can be linked to environmental factors such as water temperature (Kieffer *et al.*, 1994; Manire *et al.*, 2001). These responses include the anaerobic breakdown and mobilization of energy reserves such as glucose and glycogen to meet energetic demands and the associated accumulation of lactate (La^-) and metabolic protons (H^+) leading to lacticacidosis (Skomal and Mandelman, 2012). Changes in plasma ion concentrations can also result from lacticacidosis and drive cellular fluid shifts that result in haemoconcentration and disruptions to osmotic homeostasis (Skomal and Mandelman, 2012). A cellular stress response utilising heat shock proteins (HSPs) may also be present if cellular proteins are negatively impacted by the stress (Roberts *et al.*, 2010; Currie, 2011). Recovery from these impacts is an aerobic process fuelled partly by the oxidation of ketones (Richards *et al.*, 2003) and it has been suggested that interspecific differences in dealing with capture stress may be linked, in part, to the metabolic scope and thermal physiology of the target species (Skomal and Bernal, 2010; Skomal and Mandelman, 2012). Therefore, in understanding the implications of capture on subsequent survival it is necessary to screen for a suite of physiological and cellular markers (Skomal, 2007).

Post-release survival itself can be problematic to assess, particularly in large migratory species, where controlled experiments are not possible and conventional tag recapture studies may be limited by dispersal (Moyes *et al.*, 2006; Skomal, 2007). Satellite tags are one way of addressing survivorship in large migratory animals (Graves *et al.*, 2002; Stokesbury *et al.*, 2011); however, the cost of tags often precludes large sample sizes (Donaldson *et al.*, 2008). The recent development of specialised survivorship tags provides researchers with a more cost effective solution to this problem (Hutchinson *et al.*, 2015).

This study aimed to quantify the post-release survival rate for recreationally caught shortfin mako sharks with consideration of the nature and magnitude of the physiological response to capture. Given the high metabolic rate and aerobic scope associated with this species' thermal strategy, I hypothesised a high post-release survival rate that is independent of the level of physiological stress experienced during recreational capture.

Materials and Methods

Capture and sampling

Shortfin mako sharks were caught in south-eastern Australian waters off the coast of Tasmania (Tas), South Australia (SA) and New South Wales (NSW) using gears and methods commonly utilised by Australian game fishers when targeting this species. Sharks were attracted to the boat using chum and offered a baited hook once sighted. Each shark was allowed to take the bait and swim away from the boat before the hook was set. Gear used included 15, 24 and 37 kg rated monofilament line, joined to a ~130 kg monofilament wind-on leader and 1.6 mm stainless wire trace. Terminal tackle alternated between non-offset Shogun 9/0 stainless J (straight shank) hooks and non-offset Eagle Claw 13/0 circle hooks. Once boat-side, 26 sharks were left in the water and restrained by looping a thick, soft rope around the body posterior to the pectoral fins. Fight time (time from hook-up to restraint) was recorded to the nearest minute. The boat was kept in gear and the shark moved slowly forward facilitating ventilation of the gills. Seven sharks were manually lifted through a dive door for handling on deck; one where the tag applicator would not penetrate the skin, and six times where small (< ~50 kg) sharks either became tangled in gear or where it was deemed more efficient to handle them without the use of rope. In such instances, animals were not ventilated as to replicate game fishing conditions as closely as possible; no restraint on deck was necessary.

Once restrained or on deck, a pre-heparinised 5 mL syringe fitted with a 16 G needle was used to take a ~4 mL blood sample via caudal puncture. The sharks were measured to the nearest cm (FL) and sex and hooking location (Table 2.1) noted. Sharks were then tagged adjacent to the dorsal fin with a Survivorship Pop-up Archival Transmitting (sPAT) tag (Wildlife Computers) fitted with a Domeier umbrella anchor. Where possible the hook was removed before release; if this was not possible the trace was cut as close to the hook as possible. Each shark was examined for physical damage associated with hooking and substantial bleeding (free flowing blood that was not obviously slowed by natural haemostasis) noted. Handling time (time from restraint to release) was recorded to the nearest minute and the general condition upon release and the vigour of the shark as it swam off were also categorised (Table 2.1).

Table 2.1: Detailed definitions of variables recorded from each shark at capture.

Hooking locations	Jaw	Hooked around the jaw directly, including gums.
	Throat	Hook set behind teeth to oesophagus, excluding gill arches or filaments. Hook still visible.
	Gills	Hook set internally in gill arches or gill filaments.
	Gut	Hook set in deep oesophagus (beyond vision), and further down alimentary canal.
	Body	Hook is set in any external surface of the shark, excluding jaw.
Condition at capture	Good	Active and responsive shark with no damage beyond the hook puncture
	Average	Shark appears exhausted, is not very responsive or has sustained superficial injuries.
	Poor	Shark appears dead or dying (moribund) or has sustained heavy injuries/heavy bleeding.
Swimming vigour at release	Strong	Vigorous or high energy swimming
	Well	Regular pre-capture like swimming
	Slow	Exhausted, sluggish or buoyancy troubled
	Lifeless	No active swimming at all, drifted away

Post-release survival

Post-release survival was determined using data from the sPAT tags as per Hutchinson *et al.* (2015). These tags are pre-programmed to release and report survival after 30 days at liberty, or report prematurely if mortality occurs. Each tag summarises data in situ and transmits daily minimum and maximum temperature and depth, light change (day / night transitions) and attachment pin status (whether or not the tag has separated from the anchor). These data, along with the final pop-up location, are transmitted via Argos satellites once the tag reaches the surface and are used to determine whether the shark was actively swimming and alive at the time of release. If no movement (no depth change) is detected over 24 h or the tag exceeds 1700 m in depth, the tag will release prematurely. The fate of each tag, and therefore each shark, will fall into one of four categories; *completed deployment*, *sinker*, *sitter* or *floater*. A *completed deployment* refers to a tag still attached to a swimming animal 30 days after deployment; from this, survival is inferred as recovery from any physiological disturbances associated with the capture experience is expected to have occurred well within this deployment period (Frick *et al.*, 2010a). *Sinker* is assigned to tags that surpass 1700 m in depth, it can be assumed the tag is attached to a shark that has died and is sinking; this depth is well beyond the maximum reported for shortfin mako sharks (Abascal *et al.*, 2011). *Floater* refers to a tag that remains floating on the surface for 24 h; this may indicate attachment failure or possible fishing mortality. *Sitter* refers to a tag remaining at a constant depth that is shallower than 1700 m for 24 h, inferring the shark has died, sank and is resting on the ocean floor.

Biochemical analyses

Whole blood glucose and lactate were quantified immediately with the use of handheld meters (Accu-Chek Active blood glucose meter (Roche); Lactate Pro (Arkray)). Spun haematocrit (Hct) was determined by centrifuging blood for 5 min at Relative Centrifugal Force (RCF) 4,400 g in duplicate 75 mm mylar-coated capillary tubes plugged with Critoseal clay (ZIPocrit portable haematocrit centrifuge, LW scientific). The remaining blood was then centrifuged at RCF 2,800 g for 5 min (ZIPspin microcentrifuge, LW scientific) to separate plasma and red blood cells (RBCs), and immediately placed in liquid nitrogen for later analysis using the procedures detailed below. Long-term storage was at -80°C.

Protein levels of HSP70

Soluble protein was extracted from RBCs as per (LeBlanc *et al.*, 2012). Each sample was diluted in 200 µL of shark saline (in mM: 280 NaCl; 7 KCl; 10 $CaCl_2$; 4.9 $MgCl_2$; 8 $NaHCO_3$; 1 NaH_2PO_4; 0.5 Na_2SO_4. pH 7.8, modified from Villalobos and Renfro (2007)) before DNA was sheared. This saline was free of urea, trimethylamine oxide (TMAO) and glucose for analysis purposes, as these compounds were measured as part of the experimental protocol. The resulting supernatant was diluted 1:200 in shark saline and assayed (BioRad) at 750 nm using a $\mathrm{VERSA_{MAX}}$ microplate reader.

HSP70 was analysed based on methods developed for spiny dogfish (*Squalus acanthias)* (Kolhatkar *et al.*, 2014). 30 µg of soluble protein was run alongside a four point standard curve (5, 15, 45 and 135 ng) of HSP70/72 standard (SPP-758, Enzo Life Sciences). The primary antibody AS05-083A diluted 1:4,000 in ECL (Global anti-HSP70, Agrisera, recognizing both constitutive and inducible isoforms of HSP70). Imaging was captured in a $VERSA_{DOC}$™ imaging system (MP 4000, BioRad) with Quantity One software. Image Lab ® software (BioRad) was used to quantify band signal against the standard curve.

Plasma lactate

As Lactate Pro is designed for use on human samples, I used a plasma lactate assay to validate the results obtained from the hand meter. Plasma lactate was quantified using a NADH-linked spectrophotometric assay as described in (Currie *et al.*, 1999). Samples were incubated for 30 min after the addition of the glycine buffer before concentrations were read at 340 nm using a $VERSA_{MAX}$ microplate reader.

The values obtained from the Lactate Pro meter were tested for agreement against lactate assay values using Bland-Altman analysis (Bland and Altman, 1995, 1999; Krouwer, 2008). As a number of assay samples were compromised by equipment malfunction, this procedure allowed the use of a larger, more accurate data set with respect to lactate concentrations. Data were log transformed to account for normality and proportional error of differences during the analysis. Transformed Lactate Pro values underrepresented the assay values by a mean difference of -0.4119 ($p=.007$; $n =30$). These values were adjusted accordingly by adding 0.4119 and converted back to reflect untransformed values. The adjusted lactate values are used in all further statistical analyses.

Plasma ions

Na^+, Cl^- and K^+ were quantified by diluting plasma samples 1:2 with double distilled H_2O and analysing with a Diamond Diagnostics SmartLyte electrolyte analyser.

Osmolytes

RBC and plasma urea were measured in accordance with Kolhatkar *et al.* (2014). The saline described above was used for dilutions. Plasma TMAO was analysed by diluting samples 1:5 in cold acetone before analysis using a quadrupole linear ion trap (LTQ) mass spectrometer as described in MacLellan *et al.* (2015). 5 μL of sample was diluted in 495 μL of 50/49.9/0.1 (v/v/v) methanol/water/formic acid; this solution was then laced with 5 μL of d9-TMAO (0.01M) to give a final concentration of 0.1 mM. 10 μL of sample was injected into the mass spectrometer in triplicate. Plasma TMAO concentrations were determined by comparing the signal strengths of both endogenous and labelled TMAO and applying the appropriate dilution factor.

β-hydroxybutyrate

Plasma β-hydroxybutyrate (β-OHB) was quantified using a colorimetric assay kit (Cayman Chemical Company IN: 700190) with a $VERSA_{MAX}$ microplate reader as per manufacturer's instructions.

Statistical analyses

The 95% confidence interval associated with the survival estimate was calculated using the Release Mortality version 1.1.0 software developed by Goodyear (2002) and based on 10,000 simulations with no error sources or natural mortality incorporated, as described in Kerstetter and Graves (2006).

All other statistical analyses were carried out using SPSS (IBM) and R (R Core Team, 2014). A Kruskal-Wallis H test was used to determine if the size distributions of sharks differed between sampling regions (NSW, Tas, SA), and whether concentrations of blood parameters differed between sharks with fight times below 70 min (the bulk of the data) and four sharks with fight times that exceeded this limit (122 – 513min). The non-parametric tests were chosen as a Sharpio-Wilk test of normality indicated non-normal distributions were present in these data. Adjusted p values are presented. The association between hook type and the occurrence of foul hooking (throat, gut, body and gill locations combined) versus jaw hooking was investigated using a chi-square test. Fisher's exact test was used to determine if two uncontrolled components of my handling procedure contributed to mortality, i.e. bringing sharks on board and not removing hooks. Line class was not tested as a factor in the analyses as drag weight was not standardised.

Generalized additive models

Generalized additive models (GAMs) were used to investigate which factors (FL, SST and hooking location) influenced the length of fight time and to test the relationship between the characteristics of capture (namely: SST, fight time, handling time, whether sharks were handled on deck, hook type and hooking location) and blood-based dependent variables representing the physiological stress response.

Cleveland dotplots and boxplots were visually inspected to check for outliers in accordance with methods recommended by Zuur *et al.* (2010). Covariates were selected based on correlation matrices, Pearson's coefficients and variance inflation factors. Final selection of covariates for the model was made logically within these constraints (Zuur *et al.*, 2009; Zuur *et al.*, 2010; Zuur, 2012). Extreme data need to be removed prior to analysis in order to reduce the likelihood of type 1 and 2 errors. As such, sharks with fight times over 70 min (122 - 513 min) were omitted from GAMs to prevent the clustering caused by extreme values contributing to statistical errors; beyond this time point, relationships become based on too few data points to be considered reliable (plots of the full data are included in *Appendix I - Supplementary Figure 1* to illustrate this point).

Beginning with a fully factored model for each response variable, a stepwise, backwards elimination method was used to drop predictor variables from the model based on statistical significance and relevance until only significant predictors remained (Ambelu *et al.*, 2014). A smoothing function was applied to the primary non-linear predictor (fight time or FL) and the number of knots (inflection points) adjusted so that the spline did not indicate over-fitting (Ambelu *et al.*, 2014). All GAMs were run using the Gaussian family algorithm and Identity link function.

Results

Thirty-three shortfin mako sharks ranging between 110 – 265 cm FL (equating to 13.4 kg and 191.5 kg based on the length-weight conversion presented by Stevens (1984)) were sampled; twenty-three sharks were caught adjacent to Tas, three adjacent to SA and seven adjacent to NSW. There was no significant difference between the size frequency compositions of sharks from each region (Kruskal-Wallis test: $H = 2.190$, d.f. = 2, n = 33, $P = 0.335$).

Fight times ranged from one to 513 min. A significant relationship between fight time and fork length (F = 15.862, P < 0.0004) and fight time and SST existed (F = 4.166, P = 0.027; n = 29, GCV = 169.43, Adj $R^2 = 0.496$, Dev. Exp. = 54.8%). Larger sharks had longer fight times, and these times were extended further at warmer SSTs (Figure 2.1).

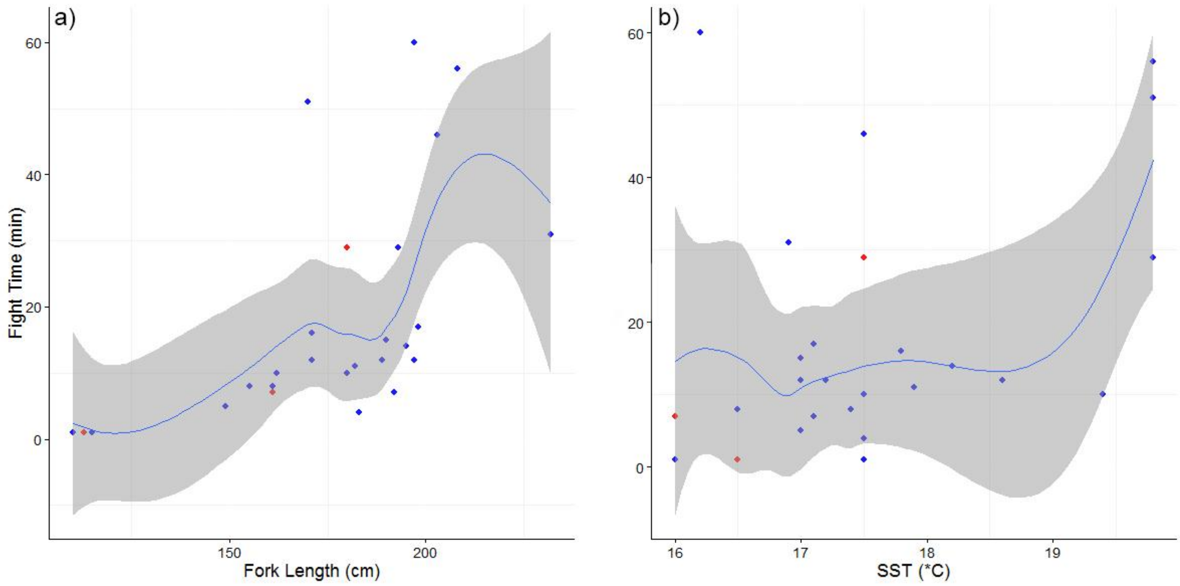


Figure 2.1: Loess smoothing functions (blue line) showing the relationship and 95% confidence intervals (grey shading) between a) fork length (cm) and fight time (minutes) and b) sea surface temperature (°C) and fight time for all sharks with fight times up to 70 minutes (n = 29). Tagged individuals (n = 26) are overlayed on the function with blue dots representing survivors and red dots indicating mortalities.

Hook type and hooking location

Of the sharks sampled, 18 (54.5%) were caught using circle hooks and 15 (45.5%) using J hooks. The majority of sharks caught using circle hooks were jaw hooked (83.3%), whereas using J hooks resulted in more variable hooking locations and a significantly lower proportion of sharks hooked in the jaw (20%) (χ^2 = 13.237, d.f. = 1, P = .0001; Table 2.2). Only one shark was observed to have substantial bleeding; it was caught using a J hook which was lodged in the gills. I was able to remove hooks from 12 sharks before release (Table 2.3).

Table 2.2: Summary of anatomical hooking locations for 33 shortfin mako sharks caught on two types of terminal tackle. J hooks are 9/0 stainless steel "Shogun" hooks, Circle hooks are 13/0 "Eagle Claw". Numbers and percentages are shown.

	J hook (% of hook type in location)	Circle hook (% of hook type in location)
Jaw	3 (20%)	15 (83.3%)
Throat	5 (33.3%)	2 (11.1%)
Gut	4 (26.7%)	0 (0%)
Body	0 (0%)	1 (5.6%)
Gills	3 (20%)	0 (0%)
Total	15 (100%)	18 (100%)

Post-release survival

Thirty sharks were tagged with sPAT tags, twenty-seven of which survived for the full duration of the 30 day tag deployment (Table 2.3), equating to a survival rate of 90% (95% Confidence Interval: 80 – 97%). The three mortalities occurred within 24 h of release and were all categorised as '*sitters*', meaning that min and max daily depth were the same, and remained constant for over 24 hours. In all instances these resting depths corresponded with bathymetry, confirming the shark was resting on the seabed. With the exception of three individuals, the sharks were generally in good condition when captured, and most swam off well (Table 2.3). Three individuals were, however, in poor condition at release; two appeared moribund and lifeless and the other exhibited severe bleeding; only the latter of these three did not survive. A blood sample was available for only one of the sharks that died, and thus I was unable to investigate the relationship between physiological stress and post-release mortality. Physiological parameters for this shark were, however, well within the ranges of all surviving individuals (Figs 2.2 - 2.5). Although two of the three mortalities were sharks that were brought on board, this handling practice did not have a significant impact on mortality ($P = 0.094$), nor did failure to remove hooks before release ($P = 0.672$).

*Table 2.3: Capture variables for all caught and released shortfin mako sharks. Sharks were caught on either 9/0 stainless steel "Shogun" J hooks or 13/0 "Eagle Claw" Circle hooks. Bleeding unknown is for deep hooked sharks where puncture location was not visible. Displacement is the distance in km from the release location after 30 days. # indicates sharks that were omitted from GAMs. * indicates sharks were brought on deck. † indicates hooks were removed before release.*

Shark	Size FL (cm)	Weight (kg)	Sex	Fight time (min)	Handling time (min)	Hook Type	Hook Location	Catch Condition	Bleeding	Swim Off	Displacement (km)	Survived	Blood Sample
M007	190	49.8	M	15	5*	J	Throat	Good	No	Slow	1042.0	Yes	No
M008	180	59.2	F	29	6*	J	Throat	Good	No	Strong	22.8	No (Sitter)	No
M009	192	50.7	M	7	8	Circle	Jaw†	Good	No	Well	1597.0	Yes	Yes
M010	189	66.4	M	12	5*	Circle	Throat†	Good	Unknown	Strong	1386.0	Yes	Yes
M012	161	42.2	F	7	4	Circle	Jaw†	Good	No	Well	21.3	No (Sitter)	No
M013#	197	77.8	F	266	2	J	Gut	Poor	Unknown	Lifeless	1350.0	Yes	Yes
M014	170	49.8	M	51	3	Circle	Body	Good	No	Well	121.0	Yes	Yes
M015	180	59.2	F	10	2	Circle	Jaw	Good	No	Well	1260.0	Yes	Yes
M016	208	91.8	N/A	56	4	Circle	Jaw	Good	No	Strong	1818.0	Yes	Yes
M017	193	74.3	M	29	3	Circle	Jaw	Good	No	Strong	52.5	Yes	Yes
M018	171	50.7	F	12	7	Circle	Jaw†	Good	No	Strong	1671.0	Yes	Yes
M019#	240	141.7	F	122	12	Circle	Jaw†	Good	No	Strong	47.9	Yes	Yes
M020	149	33.4	F	5	2*	Circle	Jaw	Good	No	Strong	344.1	Yes	Yes
M021	110	13.4	F	1	2*	Circle	Jaw†	Good	No	Strong	132.5	Yes	Yes
M022	183	62.2	M	4	2	J	Throat	Good	No	Strong	79.1	Yes	Yes
M023	115	15.3	F	1	2	J	Throat	Good	No	Strong	427.6	Yes	Yes
M024	162	43.0	F	10	2	J	Jaw	Good	No	Strong	285.9	Yes	Yes
M025	161	42.2	M	8	2	J	Gut	Good	Unknown	Well	392.8	Yes	Yes
M026	113	14.5	F	1	4*	J	Gills	Poor	Yes	Strong	0.4	No (Sitter)	Yes
M027#	182	61.2	F	160	4	J	Throat	Poor	No	Lifeless	498.3	Yes	Yes
M028#	265	191.5	F	513	12	J	Throat	Good	No	Well	1711.0	Yes	Yes
M029	110	13.4	F	4	3*	Circle	Jaw†	Good	No	Well	No Tag	Unknown	Yes
M030	232	127.8	F	31	10	J	Gills	Average	No	Well	1128.0	Yes	Yes

Table 2.3 continued…

Shark	Size FL (cm)	Weight (kg)	Sex	Fight time (min)	Handling time (min)	Hook Type	Hook Location	Catch Condition	Bleeding	Swim Off	Displacement (km)	Survived	Blood Sample
M031	197	77.8	F	12	3	Circle	Throat	Good	Unknown	Well	1918.0	Yes	Yes
M032	198	79.0	M	17	3	Circle	Jaw	Good	No	Well	756.8	Yes	Yes
M033	120	17.4	M	2	2	J	Jaw†	Good	No	Well	No Tag	Unknown	Yes
M034	197	77.8	F	60	4	Circle	Jaw†	Good	No	Strong	194.9	Yes	Yes
M035	203	85.2	M	46	5	Circle	Jaw†	Good	No	Strong	360.6	Yes	Yes
M036	182	61.2	M	11	3	J	Gills	Average	No	Slow	341.9	Yes	Yes
M037	132	23.2	F	1	1	Circle	Jaw†	Good	No	Well	No Tag	Unknown	Yes
M038	171	50.7	F	16	2	Circle	Jaw†	Good	No	Slow	318.3	Yes	Yes
M039	195	75.4	F	14	2	J	Jaw	Good	No	Well	530.4	Yes	Yes
M040	155	37.6	M	8	2	J	Gills	Good	No	Well	1652.0	Yes	Yes

Physiological response to capture

Twenty-seven of the tagged sharks were blood sampled, along with three non-tagged sharks. All thirty blood samples were analysed with field meters at time of capture, with thirteen of the frozen blood samples further analysed in the laboratory. None of the tested physiological variables (Table 2.4) were significantly related to handling time, handling on deck, hooking location or hook type.

*Table 2.4: Physiological parameters measured in blood of shortfin mako sharks. All parameters measured in mmol L^{-1} with the exception of Hct and RBC HSP70. *Values as a proxy for plasma lactate calculated from Lactate Pro values. ** Values are reported in fmol of HSP70 per µg of soluble protein from RBCs concentration.*

	Min	Max	Mean	SE	N
*La^- (mM)**	0.6	33.8	8.4	1.5	29
Glucose (mM)	4.1	8.7	6.0	0.2	29
Hct (%)	22.5	40	33.8	0.8	26
Na^+ Plasma (mM)	242	272	252.6	2.7	11
K^+ Plasma (mM)	3.4	4.4	3.9	0.1	11
Cl^- Plasma (mM)	222	240	230.1	1.4	11
Urea Plasma (mM)	306.7	399.6	353.1	9.1	11
Urea RBC (mM)	237.1	337.5	284.5	9.1	12
TMAO Plasma (mM)	97.5	195.5	139.9	7.3	11
Ratio Urea : TMAO	1.7 : 1	3.5 : 1	2.6 : 1	.15	11
β-OHB(mM)	0.212	0.910	0.567	.06	11
*RBC HSP70 (fmol.μg^{-1})***	3.05	49.23	36.6	3.9	12

For sharks with fight times up to 70 min, there were significant positive relationships between plasma lactate and increasing fight time (Figure 2.2a) and SST (Figure 2.2b) and plasma glucose and increasing SST (Figure 2.3). There were significant negative relationships between both RBC HSP70 (Figure 2.4) and plasma OHB (Figure 2.5), and increasing SST (Table 2.5).

Hct and concentrations of plasma Na^+, plasma K^+ or plasma Cl^-, urea (plasma and RBC), plasma TMAO and the ratio between plasma urea and plasma TMAO were not explained by any of the factors tested in my models.

Although not included in GAMs, sharks with fight times in excess of 70 min had significantly higher plasma lactate (H = 4.904, P = 0.026) and plasma Na^+ (H = 4.541, P = 0.033) concentrations than sharks caught within 70 min. No other blood parameters differed significantly between the two fight time groups.

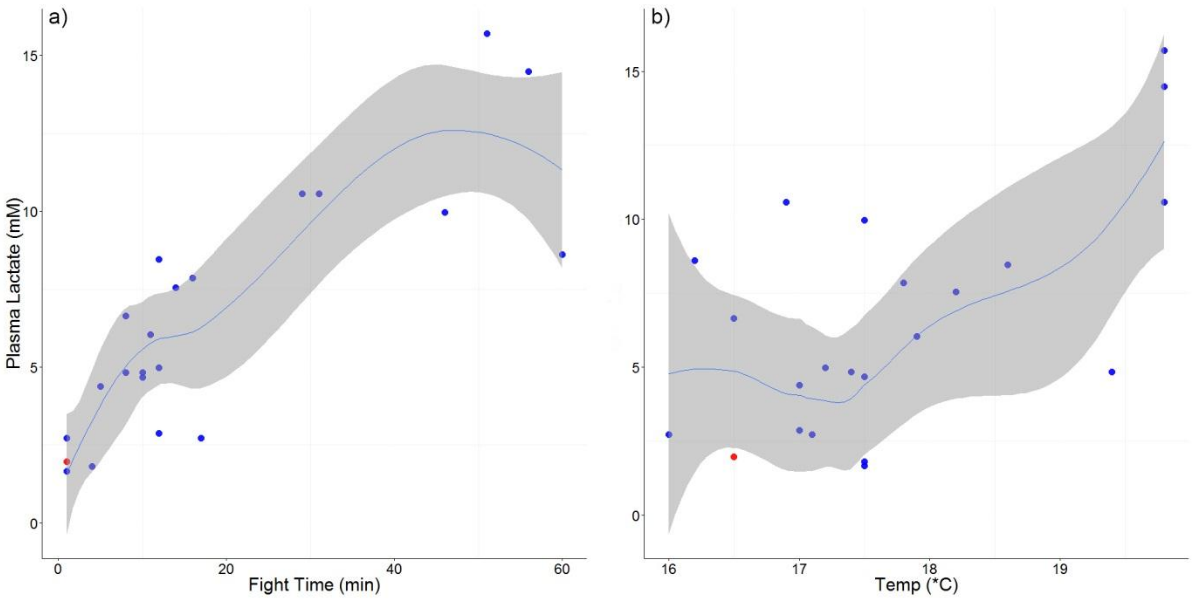


Figure 2.2: Loess smoothing functions (blue line) showing the relationship and 95% confidence intervals (grey shading) between (a) calculated plasma lactate (mM) with fight time (n = 25) and (b) calculated plasma lactate (mM) with sea surface temperature (°C) (n = 25). Tagged individuals (n = 22) are overlayed on the smoothing function with blue dots representing survivors and red dots indicating mortalities.

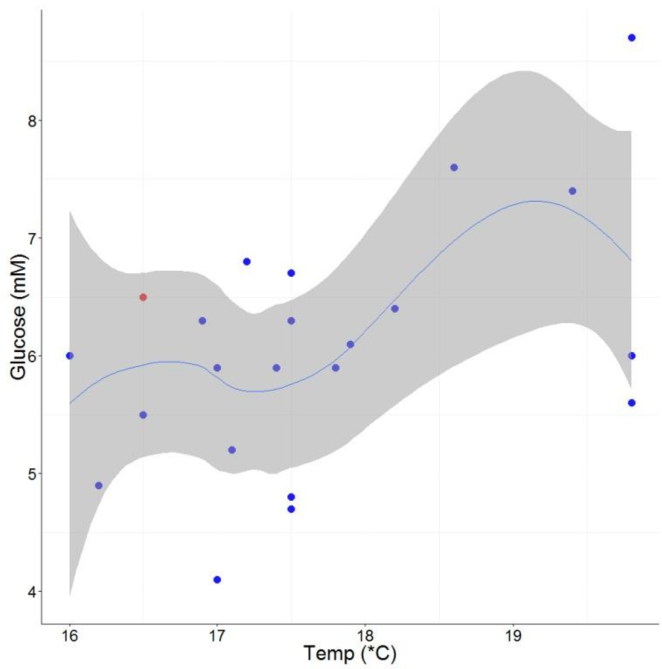


Figure 2.3: Loess smoothing functions (blue line) showing the relationship and 95% confidence intervals (grey shading) between plasma glucose (mM) (n = 25) and sea surface temperature (°C) for all sharks with fight times up to 70 minutes. Tagged individuals (n = 22) are overlayed on the smoothing function with blue dots representing survivors and red dots indicating mortalities.

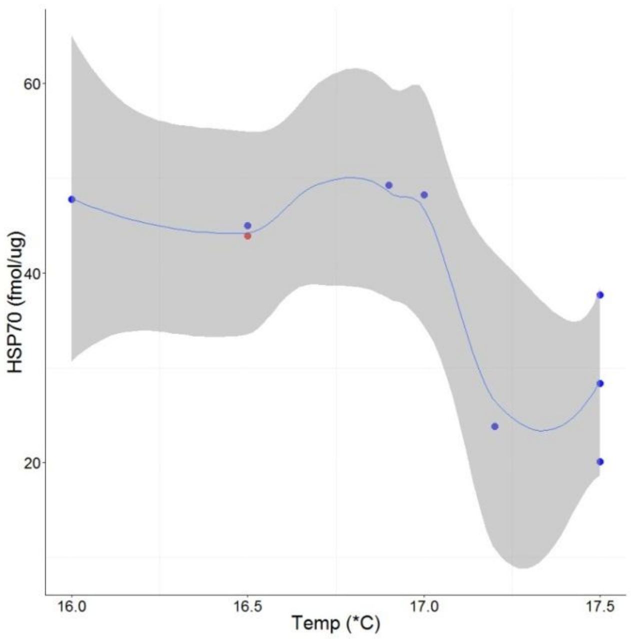


Figure 2.4: Loess smoothing functions (blue line) showing the relationship and 95% confidence intervals (grey shading) between RBC HSP70 (fmol.µg^{-1}) and sea surface temperature (^{o}C) (n = 10) for all sharks with fight times up to 70 minutes. Tagged individuals (n = 9) are overlayed on the smoothing function with blue dots representing survivors and red dots indicating mortalities.

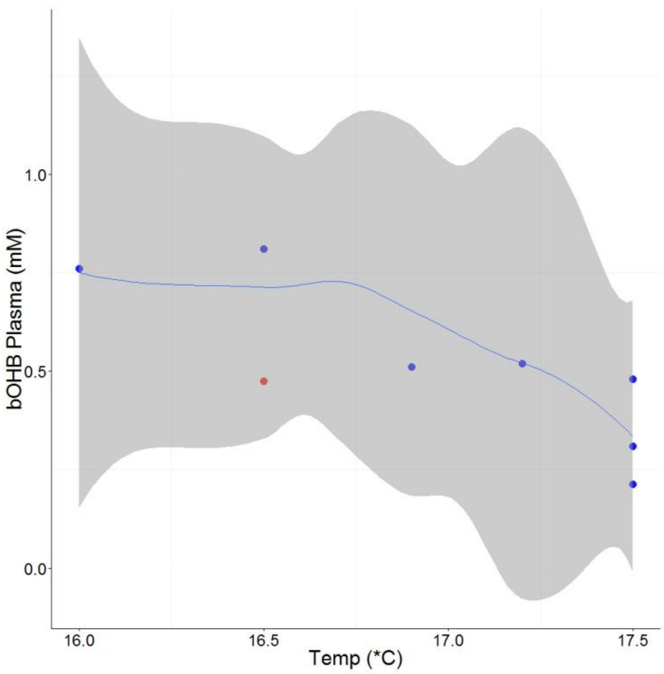


Figure 2.5: Loess smoothing functions (blue line) showing the relationship and 95% confidence intervals (grey shading) between β-OHB (mM) and sea surface temperature (^{o}C) (n = 9) for all sharks with fight times up to 70 minutes. Tagged individuals (n = 8) are overlayed on the smoothing function with blue dots representing survivors and red dots indicating mortalities.

Table 2.5: Results from GAMs examining the physiological response in sharks with fight times up to 70 mins. Only best significant models resulting from the backwards elimination approach are presented. GCV = generalised cross validation score. edf = estimated degrees of freedom. "s" indicates a smoothing function is applied to the predictor variable. Value after "k" is the number of knots used in the smoothing function.

Model	**Predictors (Best Model)**	**GCV**	**R2 Adjusted**	**Deviance Explained %**	**n**	**edf**	**F**	**P**
Plasma Lactate	s (FightTime, k3) s(SST, k3)	3.423	0.820	84.1	25	1.717 1.000	32.210 9.502	<0.0001 0.005
Glucose	s (SST, k3)	0.935	0.141	17.7	25	1.000	4.954	0.035
HSP70	s (SST, k3)	79.526	0.486	56.6	10	1.390	6.701	0.023
β - OHB	s (SST, k3)	0.036	0.474	54.0	9	1.000	8.220	0.023

Discussion

This is the first study to directly assess post-release survival and capture stress physiology for shortfin mako sharks in a recreational fishery. Overall, post release survival rate is 90% when shortfin mako sharks are caught on rod and reel and subjected to fight times up to 513 min and handled for up to 12 min. The high survival rate supports the efficacy of catch-and-release as a strategy promoting responsible fishing for this species. Plasma lactate concentrations indicate that substantial anaerobic activity was associated with resisting capture; however, no sign of disruption to ionic or osmotic or energetic homeostasis was observed with fight times up to 70 min. The limited number of sharks with fight times in excess of this threshold precludes conclusions being made about the stress response to longer angling events; although, sharks with long fight times did have significantly higher plasma La^- and plasma Na^+ concentrations. These individuals also survived, implying some degree of resilience to the increased physiological impacts of longer fight times. HSPs were elevated in cooler SSTs; a phenomenon that I believe may be linked to the thermal strategy of this species. Additionally, changes in plasma glucose and plasma β-OHB concentrations were noted with varying SSTs. Three mortalities occurred after short fight times which were not expected to provoke a strong stress response; however, two of these sharks were foul hooked. Taking this into account with the apparent resilience to capture stress, it is most likely that physical injury associated with hook choice had the greatest impact on survival in this study.

Physiological response to stress

I report an increase in plasma lactate with both fight time and SST; a relationship that has been previously noted in rainbow trout (Kieffer *et al.*, 1994; Meka and McCormick, 2005) but until now, not for elasmobranchs, nor in any aquatic endothermic species. Increases in lactate concentration with fight time alone have been observed in game fish by numerous authors and represent the most consistently reported physiological marker of exhaustive anaerobic activity (Hoffmayer and Parsons, 2001; Heberer *et al.*, 2010; Gallagher *et al.*, 2014).

Increased blood lactate is one of many physiological changes associated with exhaustive exercise, although is not thought to be directly linked to survival (Wood *et al.*, 1983; Frick *et al.*, 2010a). Nevertheless, some authors have observed significant differences in blood lactate concentrations between sharks that they have classed as either moribund or survivors (Hight *et al.*, 2007; Marshall *et al.*, 2012). Marshall *et al.* (2012) recorded significantly higher lactate concentrations in longline-caught (soak time 4-12 h) shortfin mako sharks that they classed as moribund (34.3 ± 5 mM) versus those that were classed as survivors (16.7 ± 12 mM); however, did not examine post-release survival directly, nor qualify how they classed animals as moribund. Hight *et al.* (2007) classed long-line caught sharks as moribund based on physical appearance and responsiveness. Similarly, I report lactate concentrations in sharks that are comparable to those assessed as moribund by Hight *et al.* (2007) and Marshall *et al.* (2012), and note that, despite these lactate concentrations and the moribund appearance of sharks boat-side, these individuals survived. For example, the highest recorded lactate value

(33.8 mM) was taken from a shark that was retrieved after a fight of over 4 h; this individual became tangled in the line and was retrieved tail first, appearing lifeless boat-side with no active swimming observed at release. This individual recovered and the tag was detected 30 days later, 1350 km from its deployment location. These findings demonstrate that neither plasma lactate concentration nor subjective physical measures (appearance, responsiveness) are reliable predictors of actual mortality.

Concentrations of plasma ions and Hct were comparable to those of longline-caught shortfin mako sharks (Marshall *et al.*, 2012). Changes in osmolarity and subsequent increases in haematocrit may accompany the onset of acidosis (Turner *et al.*, 1983; Cliff and Thurman, 1984; Skomal and Mandelman, 2012); however, I found no relationship between the variables included in my models and Hct or the concentrations of plasma ions. The results relating to the relationship between fight time and plasma ions are likely limited by the sample size of sharks used in the GAMs (n = 9) and the four sharks with fight times over 70 min being omitted from this analysis. This is supported by the significantly higher distribution of plasma Na^+ concentrations that I observed in these four sharks relative to the others and suggests that longer fight times may still provoke an ionic response to capture stress in this species.

The osmolytes urea and TMAO are a key component of the elasmobranch osmoconformation strategy (Yancey and Somero, 1979; Treberg *et al.*, 2006). This is the first study to examine TMAO in an endothermic shark species, with plasma concentrations in the shortfin mako shark (139.9 ± 7.3 mM) at similar levels to those measured in ectothermic species such as Port Jackson sharks (*Heterodontus portusjacksoni*) (mean = 121 mM; Cooper and Morris (1998)). My values for plasma urea (353 ± 9.1 mM) were comparable to other reports for this species following angling (322 mM; n = 2; (Wells *et al.*, 1986)) and levels reported for ectotherms such as Port Jackson (394 mM) and gummy sharks (*Mustelus antarcticus*) (377 mM; (Frick *et al.*, 2010a)). There have been reports of significant decreases in plasma urea in response to otter-trawl capture and transport in spiny dogfish (Mandelman and Farrington, 2007) and gillnet capture in gummy sharks (Frick *et al.*, 2010a), which are likely attributed to a stress-induced increase in gill surface area and urea permeability (Evans and Kormanik, 1985). However, I did not observe any relationship between fight time and either osmolyte; nor did I find a significant difference in the concentrations of these osmolytes between sharks included in my model and those with long fight times. These findings support those of Brill *et al.* (2008) who reported no difference between the plasma urea levels of control and exercise-stressed sandbar sharks (*Carcharhinus plumbeus*). The utility of urea and TMAO as indicators of the stressed state in elasmobranchs remains unclear as also concluded by Skomal and Mandelman (2012).

The ketone, β-OHB, plays an important role in the supply of energy for exercise recovery; its oxidation supplying about 20% of the ATP required by *S. acanthias* (Richards *et al.*, 2003). It is also an important energy source for the heart and red muscle in elasmobranchs (Ballantyne, 1997) and therefore plays an integral role in exercise physiology. I observed no relationship between plasma β-OHB concentrations and fight time which may be explained by the white muscle uptake of plasma ketones occurring at the same rate as their supply from the liver

(Richards *et al.*, 2003). I did find a significant negative relationship between β-OHB and SST for sharks caught within 70 min; however, the reason for this relationship is uncertain. β-OHB concentrations in this study (0.567 ± 0.06 mM) are comparable with those previously reported for mako sharks (0.978 mM (Watson and Dickson, 2001)), and the lack of exceptionally high values (~5 mM) would suggest that none of the sharks in this study were affected by starvation events (Walsh *et al.*, 2006; Wood *et al.*, 2010). Assuming starvation can contribute to poor health and negatively impact the energy available for metabolic processes such as swimming and recovery; my β-OHB data suggest that the sharks in this study were not starved or energy-depleted. I also observed a positive relationship between blood glucose and SST, with increased blood glucose possibly reflecting an increase in metabolic rate associated with the warmer SSTs and potentially an increase in feeding frequency that is necessary to sustain these increased energetic demands (Hoffmayer *et al.*, 2012).

When all cells experience protein-damaging stress , HSPs are up-regulated within minutes to facilitate recovery of protein structure by guiding refolding, preventing protein aggregation and targeting irreparable proteins for destruction (Roberts *et al.*, 2010; Currie, 2011). I examined the impacts of fight times of up to 70 min on cellular function by quantifying one of the most highly conserved of the stress proteins, HSP70 (Roberts *et al.*, 2010; Currie, 2011). No relationship between RBC HSP70 and fight time was found, although interestingly, I found a significant negative relationship between RBC HSP70 and SST. This is a surprising relationship and one that conflicts with what is known about the heat shock response in teleosts; specifically, that HSP70 usually increases at warmer temperatures (Currie, 2011). Given that the shortfin mako is an endothermic elasmobranch (Bernal *et al.*, 2001) capable of maintaining body temperatures 7-10^{o}C above ambient (Carey and Teal, 1969), the higher RBC HSP70 levels in cooler waters may be a response to a larger temperature difference experienced by the blood as it circulates from the cool periphery to the warm core of the fish. Additionally, increased HSP70 expression may reflect an elevated metabolic rate in response to the cold, as observed in the splenic tissue of Pacific Bluefin tuna (*Thunnus orientalis*) (Mladineo and Block, 2009). Skomal and Bernal (2010) present data showing HSP70 expression in shortfin mako sharks with 30 – 45 min fight times to be six times higher than in those on the line for < 1 min; however, the use of relative HSP70 levels and the absence of temperature data presented by these authors prevent any direct comparisons being made with my findings. It is possible that the strong relationship I observed between RBC HSP70 and SST dominated any effects that fight time may have had under a constant temperature. Further research is certainly needed to understand how endothermic fishes utilise HSPs during stress events and under varying environmental conditions.

Effect of fight time

Decreased survival associated with long fight times was not observed in this study, differing from previous reports on pelagic sharks in both commercial (Campana *et al.*, 2009; Gallagher *et al.*, 2014) and recreational fisheries (Heberer *et al.*, 2010). Growth, digestion and exercise recovery all require the delivery of oxygen and metabolic substrate to the tissues at rates above those required by routine activities (Brill, 1996). Hence, elasmobranchs with a high aerobic scope should be capable of supplying more oxygen to tissues to deal with multiple aerobic demands (such as swimming and recovering from stress) simultaneously. This may also enable them to cope with a greater magnitude of physiological disruption from exercise and recover faster from this relative to their less active counterparts (Priede, 1985; Brill, 1996; Sepulveda *et al.*, 2007; Skomal and Bernal, 2010).

Heberer et al. (2010) identified fight time as a significant predictor of survivorship for tail hooked common thresher sharks (*Alopias vulpinus*), with all sharks on the line ≥85 min succumbing to mortality. However, the capture method used by Heberer *et al.* (2010) involved pulling sharks backward, preventing effective ram ventilation and, in turn, limiting the aerobic capacity of the common thresher sharks. In contrast, my results indicate that all individuals with fight times over 85 min (n = 4, max 513 min) survived. As it is unlikely that respiration was inhibited by my capture method, oxygen delivery was not limited and it is probable that the shortfin mako's ability to cope with multiple aerobic demands was not compromised. Moreover, the three mortalities that I did observe had fight times < 30min, suggesting that mortalities in this study were not likely to be a direct consequence of the physiological impacts of fight time and indicate that this species may be more vulnerable to physical damage resulting from gear use and handling.

Effect of gears

My data indicate a much higher occurrence of foul hooking associated with the use of J hooks compared with circle hooks. Foul hooking has been shown to significantly increase mortality rate in a number of species (Bartholomew and Bohnsack, 2005; Reeves and Bruesewitz, 2007; Campana *et al.*, 2009; Epperly *et al.*, 2012; Kneebone *et al.*, 2013) and for the shortfin mako in particular, foul hooked sharks were over four times more likely to be retrieved from longlines dead than jaw hooked sharks (Epperly *et al.*, 2012). Two of the three mortalities observed in this study were foul hooked sharks caught using J hooks. One was gill hooked, with the associated bleeding almost certainly the cause of death; the other was deep hooked, possibly sustaining internal injuries or bleeding. Necropsy has shown foul hooking to be associated with hook penetration of the pericardium (Kneebone *et al.*, 2013) and vital organs such as the heart, liver and parts of the lower alimentary canal (Caruso, 2000; Borucinska *et al.*, 2001; Borucinska *et al.*, 2002). Retained hooks can also lead to mortality over longer periods by causing systemic diseases (Borucinska *et al.*, 2001; Adams *et al.*, 2015). The significant reduction in foul hooking that I observed with circle hook use is in agreement with the findings of many other authors (Caruso, 2000; Cooke and Suski, 2004; Bartholomew and Bohnsack, 2005; Mapleston *et al.*, 2008; Pacheco *et al.*, 2011). It should be noted that although circle hooks are better for fish welfare in the majority of instances, offsetting circle hooks can counteract their conservation benefits by increasing deep hooking and subsequent mortality (Cooke and Suski, 2004; Epperly *et al.*, 2012; Rice *et al.*, 2012). The circle hooked shark that died in this study was hooked in the jaw and appeared to be in good health;

however, no blood sample was taken, therefore I cannot speculate on the reasons for this mortality beyond the increased risk of predation during recovery.

Other survival estimates published for this species relate to individuals mostly taken on longlines and are based on tag-recapture data, 79% (Wood *et al.*, 2007) and estimates from quantifying catecholamines at release, 80% (Hight *et al.*, 2007). The lower survival estimates presented by these studies likely reflect the differences in capture and handling techniques between commercial and recreational fisheries; a finding consistent with blue shark (*Prionace glauca*) hooking mortality between the two sectors (Campana *et al.*, 2006). When compared to other active sharks that exhibit a physiological response to capture of similar magnitude, the shortfin mako, and other lamnids, have an apparently high level of survivorship (Marshall *et al.*, 2012) indicating a resilience to the physiological stresses of capture.

Previous work suggests that the activity level and ecological classification of elasmobranchs will affect the magnitude of their response to capture (Marshall *et al.*, 2012). Taking into account the data presented by Marshall *et al.* (2012) and the results of this study, I suggest that the mako shark, a species renowned for its high activity, is resilient to capture stress due to the metabolic rate and aerobic scope attributed to its endothermy. Other active species, lacking the aerobic scope of endotherms, may differ in their ability to recover from intense exercise whilst simultaneously performing other necessary aerobic processes. As a result, these species may exhibit high mortality rates associated with their limited aerobic capacity, for example: blacktip shark (*Carcharhinus limbatus*, 88% mortality) and dusky shark (*C. obscurus*, 81% mortality (Marshall *et al.*, 2012)). The data presented by Marshall *et al.* (2012) also suggest that some less active species have relatively high survivorship (e.g.: tiger shark, (*Galeocerdo cuvier*)) and do not appear to become as physiologically perturbed as active sharks (Marshall *et al.*, 2012; Gallagher *et al.*, 2014). This suggests that less active sharks do not require the aerobic scope associated with endothermy to deal with capture stress; rather, these species avoid substantial physiological perturbation altogether, suggesting divergent strategies in dealing with capture stress between active and less-active species.

Summary

Fight time did not impact shortfin mako shark survival, despite elevated plasma La^- and plasma Na^+ after long fight times indicating pronounced metabolic acidosis. This highlights the species' resilience to capture stress and likely reflects the aerobic capabilities associated with endothermy. No other physiological responses were found to be related to the duration of the capture event. Fight times reported in this study represent those that would be imposed by recreational fishers and give merit to the use of catch-and-release fishing as a conservation method for shortfin mako. Post-release survival in this species is most likely to be impacted by hooking injuries which can be reduced through the adoption of circle hooks. If sharks are deep hooked, my results indicate that leaving hooks in may be beneficial, rather than risk further internal injury trying to remove them (Bartholomew and Bohnsack, 2005; Kneebone *et al.*, 2013). Furthermore, sharks that appeared moribund when boat-side were observed to make a complete recovery after release which is an important factor to take into consideration when conducting survivorship studies and when making a decision about whether or not to release an individual. Recent studies have highlighted the highly interspecific nature of the stress response in sharks (Marshall *et al.*, 2012; Renshaw *et al.*, 2012) and species can differ greatly in their ability to cope with physiological disruptions (Renshaw *et al.*, 2012); this may particularly apply when comparing ectothermic and endothermic species. Additionally, the need for fishery-specific assessments may be as equally important as species-specific assessments where gears and handling techniques are expected to vary between users.

Chapter 3
Understanding the Catch-and-Release Behaviour of a Specialised Group of Anglers

Effective management of a fishery depends on understanding and cooperating with the human users of the resource, particularly as policies may be rejected if angler satisfactions are not met. In Australia, the shortfin mako shark (*Isurus oxyrinchus*) is legally able to be targeted by recreational anglers based on the assumption that most of the sharks are released and populations remain minimally impacted. However, the actual release rate of this species is unknown and little information is available on the motivations and satisfactions of anglers that participate in this fishery. It is important to understand what motivates anglers to practise catch-and-release and how often they do so, as this information can assist management authorities in identifying the extent of current impacts on fisheries resources and how best to minimise these impacts through the effective promotion of catch-and-release fishing. This study utilised a targeted web survey to obtain information regarding the current level of catch-and-release fishing for shortfin mako sharks and how this behaviour changes between various angler groups. Information presented is based on the responses from 287 shortfin mako anglers distributed across south eastern Australia. Overall, respondents reported releasing approximately 70% of the sharks that were caught, with the greatest variation in release rates being observed between states. Club membership was not related to the catch-and-release behaviour of respondents despite club members identifying as more specialised anglers than non-members. Differences in fishing behaviour between states can be attributed to the varying value of shortfin mako as a sport fish and table fish between regions. Additionally release rates are likely higher in NSW due to the increased opportunity for resource substitution and the established norms driven by current catch-and-release fisheries in that region. Increased participation in catch-and-release fishing may be achieved by establishing behavioural norms within fishing clubs by the provision of more desirable incentives to release sharks during fishing competitions.

Introduction

It is increasingly apparent that recreational fisheries have the potential to significantly impact fish populations and their ecosystems (Mc Phee *et al.*, 2002; Post *et al.*, 2002; Cooke and Cowx, 2004; Arlinghaus *et al.*, 2005; Lewin *et al.*, 2006). In some cases the recreational harvest exceeds that of commercial operations, including vulnerable and high value species (Coleman *et al.*, 2004; Arlinghaus *et al.*, 2005; Lewin *et al.*, 2006). In these instances, catch-and-release fishing is often promoted by fisheries managers and recreational fishers themselves as a strategy to reduce the harvest whilst maintaining the availability of quality fishing opportunities (Sutton and Ditton, 2001; Policansky, 2002; Sutton, 2003; Arlinghaus *et* *al.*, 2007a). However, catch-and-release fishing is often promoted with limited understanding of how the policy will be received by anglers (Frijlink, 2011).

Effective fisheries management not only requires a focus on sustaining the populations of the target species and their environment, but also understanding and cooperating with stakeholders, as policies may be rejected without their support (Fisher, 1997; Nielsen, 1999). This is particularly true of recreational fishers, where motivations for fishing vary and fishing effort may not be limited by economic factors as it is in commercial fisheries (Post *et al.*, 2002; Lyle *et al.*, 2014). Where catch-and-release has been shown to be effective in reducing fishing mortality whilst maintaining access to a target species (Chapter 2; Graves and Horodysky, 2008; Stokesbury *et al.*, 2011; Sepulveda *et al.*, 2015), it is important to understand factors influencing catch-and-release behaviour as well as those that might drive resistance to uptake of the practice. This understanding can assist management in the promotion of catch-and-release and the estimation of current and future catch-and-release participation rates (Sutton and Ditton, 2001; Frijlink, 2011; Heard *et al.*, 2016).

Early research on catch-and-release participation was largely descriptive (Grambsch and Fisher, 1991; Graefe and Ditton, 1997), with the definition of catch-and-release fishing also varying between studies (Ditton, 2002; Fedler, 2002). However, Sutton (2001) developed a formal theoretical framework for investigating the causative reasons for voluntary catch-and-release. This work hypothesised that an angler's decision to release fish was determined by their commitment to angling (specialisation), their consumptive orientation and situational factors specific to the fishing event, such as the size of the fishing party, hours fished, and the number of different species caught. Specialisation is comprised of a number of sub-dimensions that relate to an angler's experience, avidity, skill level and the centrality of fishing to the angler's lifestyle (Ditton *et al.*, 1992; Salz *et al.*, 2001). In contrast, consumptive orientation measures the importance of certain catch related variables to the angler; namely, catching numbers of fish, keeping fish, catching a trophy fish and catching something (Fedler and Ditton, 1986; Anderson *et al.*, 2007; Kyle *et al.*, 2007). These hypotheses were subsequently tested over three different studies (Sutton, 2001; Sutton and Ditton, 2001; Sutton, 2003) and revealed differing results within the domains of specialisation and consumptive orientation between the three populations studied, with the authors cautioning on the generalisation of their results across other angler populations.

It is very unlikely that specialisation, demographic characteristics or the satisfactions gained from the angling experience, such as those that relate to consumptive orientation, will dictate all aspects of an individual's fishing behaviour; hence it is important to understand the motivations behind particular fishing behaviours as well (Hunt *et al.*, 2002; Hutt and Bettoli, 2007; Heard *et al.*, 2016). Subsequent research has used a range of survey techniques in an effort further our understanding of angler behaviour (Hunt *et al.*, 2002; Salz and Loomis, 2005; Sutton and Ditton, 2005; Anderson *et al.*, 2007; Kyle *et al.*, 2007; Wallmo and Gentner, 2008; Frijlink, 2011; Dorow and Arlinghaus, 2012; Heard *et al.*, 2016). Many of these studies utilise general indices of specialisation and consumptiveness but it is unknown how these generalised question designs may impact responses when surveys are focused on specific fisheries or activities. The assumption that the importance placed on catching, keeping and releasing fish for an individual will be uniform across all species and geographic areas is an unlikely prospect. Different species will have varying value as food items or sport fish (Wallmo and Gentner, 2008; Tracey *et al.*, 2013b) and may also have important conservation (Chapter 2; Jensen *et al.*, 2009; Bruce, 2014; Heard *et al.*, 2016), economic (Hickley and Tompkins, 1998; Shrestha *et al.*, 2002; Galeano *et al.*, 2004; Duffield *et al.*, 2007; Prayaga *et al.*, 2010; Frijlink, 2011) and social (Kellert, 1985; Philpott, 2002; Neff and Yang, 2013) attributes. Even for a given target species, the above values are likely to vary regionally as cultures, access to alternate fishing opportunities, species availability, public perceptions and fisheries regulations may vary between countries (Graefe and Ditton, 1997; Sutton, 2001), their states or territories (Grambsch and Fisher, 1991; Henry and Lyle, 2003; Sutton and Ditton, 2005; Rogers and Bailleul, 2015) and specific localities within these areas (Grambsch and Fisher, 1991; Hutt and Bettoli, 2007). Examining geographic differences in angler behaviour is particularly important when management jurisdictions are separated at these spatial levels.

Increasingly, game fishing clubs and organisations are promoting catch-and-release fishing by offering prizes in angling tournaments for numbers of tagged and released fish. While this is a positive incentive for anglers to practise catch-and-release fishing, these prizes are often offered alongside prizes (often of greater value) for heaviest catch; which to a degree hampers efforts to promote catch-and-release through fishing clubs. Additionally, angling tournaments are only open to fishing club members in many regions, so there is a disconnect in the incentives available to club members and non-members to practise catch-and-release, and as such practices between these groups likely vary (Zischke *et al.*, 2012).

The shortfin mako shark (*Isurus oxyrinchus*) is the most important target species of shark for recreational game fishers in the south-eastern states of Australia (New South Wales (NSW), Victoria (Vic), Tasmania (Tas) and eastern areas of South Australia (SA)) (Rogers and Bailleul, 2015), and many other parts of the developed world. It is targeted for its ‘fighting’ abilities and the quality of its flesh for consumption (Wells and Davie, 1985; Stevens, 2008). In 2010, following population declines in the northern hemisphere and subsequent listings as ‘vulnerable’ by the International Union for Conservation of Nature (IUCN) and ‘migratory’ by the Convention on the Conservation of Migratory Species (CMS), the shortfin mako shark was listed as a protected species in Australia under the Environment Protection and Biodiversity Conservation (EPBC) Act. A controversial political debate around the protection of the species in Australia resulted in the shortfin mako shark remaining available to be targeted by recreational anglers only, under the assumption that the retained catch is relatively low and that populations remain minimally impacted by the fishery (Chapter 2; Bruce, 2014; Rogers and Bailleul, 2015). There is little information available on the catch of shortfin mako by recreational fishers or the catch-and-release participation rate for anglers of this species; hence, uncertainty remains as to the sustainability of current harvest levels.

This study aims to investigate the extent to which catch-and-release fishing has been adopted by recreational fishers when targeting shortfin mako sharks in Australia. This information will give some insight into the current impact of recreational fishing on Australian mako populations. As catch-and-release has been shown to be an effective conservation measure for this species (Chapter 2), I also investigate how to maximise the adoption of catch-and-release fishing throughout the angling community by identifying the characteristics and motivations of angler groups that are already predisposed to practise catch-and-release. A targeted online survey was used to examine fishing behaviour in relation to specialisation, consumptive orientation and motivations for catching, keeping and releasing shortfin mako sharks. These attributes are compared across the fishing club membership (club members vs non-members) and the residence (state; Vic, Tas or NSW) of anglers in an effort to identify existing angling cultures and inform regulators where educational efforts may best be applied for the most effective promotion of management strategies. I also compare general consumptive orientation to species specific consumptive orientation in order to illustrate how angler attitudes towards releasing fish are influenced by target species, and how general measures of consumptive orientation may provide misleading results if extrapolated to species-specific situations.

Methods

Distribution

A structured questionnaire was designed using the online platform ‘Survey Monkey’ and distributed as a web-based survey targeted at anglers who had caught and/or targeted mako sharks in the previous 12 months. The questionnaire was pilot tested with a small group of experienced recreational fishers to refine questionnaire structure, flow and address potential misunderstanding or ambiguities in the questions prior to its implementation.

Fishing club members only comprise a small percentage of the overall fishing population (Henry and Lyle, 2003), yet often become the focus of human dimensions studies (e.g.: Heard *et al.* (2016)). As such I was interested in obtaining responses from both anglers belonging to fishing clubs affiliated with the Game Fishing Association of Australia (GFAA) and those that were not affiliated with game fishing clubs. The questionnaire was made accessible to the public between 08/05/2014 and 02/09/2014. It was promoted via game-fishing web forums (3 representing Tasmanian anglers, 2 representing Victorians and 2 for anglers in New South Wales), social media (through pages associated with game fishing, fisheries management and the “post boost” function via Facebook) and participating game fishing clubs (promotional information and instructions were sent to club presidents and secretaries belonging to GFAA registered clubs in each of the three states). The survey was also promoted by Australian game fishing celebrities via social media. The chance to win a game fishing reel was provided to respondents as incentive to complete the questionnaire.

Questionnaire design

The self-administered questionnaire was separated into seven sections; ‘catch-and-release preferences’, ‘specialisation and consumptive orientation’, ‘gear use and perception of circle hooks’, ‘perceptions of sharks and shark survival’, ‘attitudes towards management’, ‘fishing behaviour and motivations’ and ‘demographics’. The four of these relevant to the current study are explained in more detail below.

Demographics

This section collected information on the age, gender, home post code, employment status, and highest level of completed education for each respondent. Whether the respondent was a member of a fishing club and the state in which they most commonly fished for mako sharks was also asked.

Catch-and-release preferences

This section examined the motivations and preferences associated with stated behaviour in relation to catch-and-release of makos. Respondents were asked to rate which of five statements best describes their fishing method. The statements ranged from “I release all of the mako sharks I catch” to “I never release a mako shark unless I have to”; this stated fishing behaviour is referred to as the anglers ‘release philosophy’ throughout this text. This was followed up by preference questions on keeping or releasing sharks based on their size. Anglers were then asked to rate their agreement with 12 statements, which were comprised of six possible reasons for releasing sharks that could have been legally retained, and six possible reasons for keeping sharks that could have been released. Respondents who indicated that they either always released, or never voluntarily released their catch were only presented with the six statements applicable to their situation.

Specialisation and Consumptive Orientation

Specialisation was measured using a scale modified from that used by Sutton and Ditton (2001) which incorporates previous experience and centrality to lifestyle components. As a measure of experience anglers were asked to estimate their fishing experience in years, the number of days they had fished in salt water in the previous 12 months and the number of days they had spent fishing for mako sharks during the same period. The measurement of centrality to lifestyle incorporated the number of subscriptions to fishing related magazines, the respondent’s self-perceived skill level, the importance of fishing relative to other outdoor activities and the importance of fishing for makos relative to other types of fishing.

Consumptive orientation was measured using a scale modified from that first utilised by Graefe (1980) and subsequently refined by others (e.g.: Sutton and Ditton (2001); Anderson *et al.* (2007); Kyle *et al.* (2007); Frijlink (2011)). The current study omitted some repetitive questions from existing scales to form a final nine question scale. Two questions relate to ‘catching something’, one question to ‘catching numbers’, three questions to ‘catching a trophy’ and three questions to ‘keeping the catch’. This nine item scale was presented to respondents twice, initially worded to apply to recreational fishing in general and the second time worded specifically to apply to fishing for makos. This was done to investigate whether consumptive orientation differs between general fishing activities and the targeting of mako sharks.

Motivations and behaviour

This section asked respondents to rate eight motivations for fishing mako sharks along a five point Likert scale (Likert, 1932) ranging from “not at all important” to “very important”.

Respondents were also asked to report the total number of mako sharks caught and total number released in the previous 12 months; this response allowed comparisons to be made with stated behaviour.

Analysis

All statistical analyses were conducted using R (R Core Team, 2014). I was interested in comparing the catch-and-release behaviour, demographics, specialisation, consumptive orientation and motivations of anglers between their state of residence (Tas, Vic or NSW) and club membership.

Creating valid scales

The scales for specialisation and consumptive orientation were based on frameworks presented in Sutton and Ditton (2001). The fit of these frameworks to my data was investigated using confirmatory factor analysis (CFA) (Anderson *et al.*, 2007; Kyle *et al.*, 2007), with an acceptable model fit based on criteria recommended by Hu and Bentler (1999) and Schreiber *et al.* (2006). CFA is widely used for examining relationships between Likert type variables (Flora and Curran, 2004). Prior to the CFA, the general and specific consumptive orientation scales were tested for multivariate normality using the MVN package (Korkmaz *et al.*, 2014) and subsequently "Diagonally Weighted Least Squares" (DWLS) was chosen as the estimation method for use in the CFA (Mindrila, 2010). The CFA model was carried out using the Lavaan package for R (Rosseel, 2012). Factor loadings, z-values and measure of internal consistency (Cronbach's alpha or Spearman's coefficient where appropriate) are presented. Where an acceptable model fit was found, new parameters were created representing each dimension by averaging its constituent variables.

Comparisons between groups

Catch-and-release behaviour, demographics, specialisation, consumptive orientation and angler motivations were then compared between club and non-members using independent sample Mann-Whitney U tests and between states using Kruskall-Wallis H tests, as is recommended for the analysis of non-normal data (Lantz, 2013). Significant results from Kruskal-Wallis tests were followed up by pairwise comparisons with p values adjusted using the Bonferroni-Dunn method (Dunn, 1964; Pohlert, 2014). Paired Wilcoxon tests were used to compare angler responses between general and mako specific consumptive orientation scales. Linear regression was used to test the relationship between the days spent fishing for mako and the percentage of sharks released. Spearman's rho was used to examine the relationship between the reported percentage of sharks released and release philosophy, and the relationship between days spent fishing for mako and release philosophy.

Results

Description of the sample population

A total of 325 survey responses were received, two of which were excluded because they were not completed correctly and a further 36 were excluded prior to analysis due to reporting spending no days targeting makos and a nil catch of mako sharks in the previous 12 months. Respondents who reported not targeting makos during the previous 12 months but reported catching the species were, however, included in the analyses.

Of the 287 remaining respondents, 107 (37%) were members of fishing clubs, 165 (57%) reported having no affiliation with any fishing clubs or organisations and 15 (5%) respondents did not provide an answer to this question. The distribution of respondents was roughly equal between NSW, Vic and Tas (n = 82, 74 and 112 respectively), with four anglers responding from SA and 15 not answering this question. SA anglers were omitted from all further comparisons by state due to low sample size.

Demographic information for respondents can be found in Table 3.1. Fishing club members were significantly older than non-members ($W = 4568$, $p = 0.01$). No other significant differences in demographic information existed between club members and non-members or between each state of residence.

Table 3.1: Demographic information of respondents. Age was measured in years. Gender was coded as female (0) and male (1). Education was coded as year 12 and under (0), Trade Qualification or Diploma (1) or Degree (2). Employment was coded as Part time, casual, self-employed, student, unemployed, retired or pensioner (0) or full time work (1).

Variable	**Club Membership**	**Mean**	**SD**	**Min**	**Max**	**n**
Age	Club member	37.8	11.59	13	70	91
	Non-member	33.8	10.58	14	61	126
Gender	Club member	1	0			91
	Non-member	1	0			126
Education	Club member	1.0	0.63	0	2	91
	Non-member	0.92	0.74	0	2	126
Employment	Club member	0.73	0.45	0	1	91
	Non-member	0.67	0.47	0	1	126

Catch-and-release data

Combined, respondents reported catching a total of 871 sharks (mean = 3) in the 12 months prior to the survey, with 636 (73%) of these sharks released (mean = 2.2).

There was a significant relationship between the percentage of sharks released and the release philosophy of each respondent (rho = -0.58, P <0.0001), which demonstrates agreement between reported and stated behaviour (*Figure 3.1*).

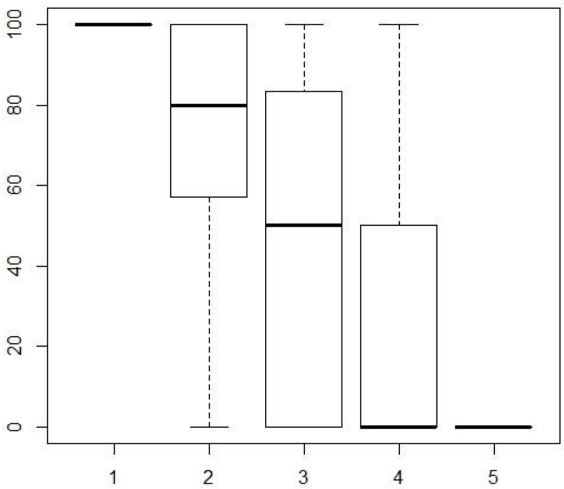


Figure 3.1: Boxplot showing the agreement between Release Philosophy on the x axis, and release percentage on the y axis. Release Philosophy values: 1 = I release all of the mako sharks I catch, 2 = I mainly practise voluntary catch-and-release, but will retain the occasional mako, 3 = I practise voluntary catch-and-release and harvest fishing equally for mako sharks, 4 = I mainly keep makos, but will practise voluntary catch-and-release on occasion, 5 = I never release a mako shark unless I have to.

Fishing club members were found to have caught a significantly higher number of sharks than non-members; however there was no difference in the percentage of sharks released between these two groups (*Table 3.2*). NSW anglers released a significantly higher proportion of their catch than anglers from both Vic and Tas (*Table 3.2*).

Table 3.2: Summary of information relating to the catch-and-release behaviour of Australian mako anglers. Release Philosophy was measured when respondents best described their fishing method as: I release all of the mako sharks I catch (1), I mainly practise catch-and-release fishing, but will retain the occasional mako (2), I practise voluntary catch-and-release fishing, and harvest fishing equally for mako sharks (3), I mainly keep makos, but will voluntarily practise catch-and-release on occasion (4), I never release a mako shark unless I have to (5).

Catch or Release Parameter	**State / Club Member**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
In the last 12 months, how many mako sharks did you personally catch, whether you kept or released them?	NSW	3.32	4.37	2	H = 4.928	0.085		
	Vic	2.27	3.26	1				
	Tas	3.11	4.20	2				
	Club Member	4.07	4.62	3	W = 6445.5	0.0001		
	Not Member	2.21	3.37	1				
In the last 12 months, how many of the mako sharks that you caught did you release?	NSW	2.82	4.10	2	H = 11.978	0.002	NSW – Vic	0.0016
	Vic	1.32	2.34	0			NSW – Tas	0.174
	Tas	2.15	3.69	1			Vic - Tas	0.187
	Club Member	2.95	4.01	2	W = 6645	0.0003		
	Not Member	1.59	3.07	1				
Percentage of Sharks Released	NSW	82.35	30.69	100	H = 26.563	<0.0001	NSW – Vic	<0.0001
	Vic	50.73	39.02	50			NSW – Tas	<0.0001
	Tas	58.99	38.36	66.67			Vic - Tas	0.85
	Club Member	67.18	34.63	79.29	W = 4896.5	0.800		
	Not Member	62.34	40.67	75				
Release Philosophy	NSW	1.88	0.85	2	H = 40.018	<0.0001	NSW – Vic	<0.0001
	Vic	2.79	0.96	3			NSW – Tas	<0.0001
	Tas	2.48	0.97	2			Vic - Tas	0.084
	Club Member	2.37	0.97	2	W = 7291.5	0.987		
	Not Member	2.38	1.00	2				

Specialisation

Respondents fished a total of 2143 days for mako in the previous 12 months, with no apparent relationship between the number of days spent fishing for mako and the percentage of sharks released ($F = 2.392$, $P = 0.124$), or the number of days spent fishing for mako and release philosophy ($rho = 0.098$, $P = 0.125$). Factor analysis indicated that each component of the specialisation index described too much of the variation to be collapsed into the sub-dimensions of experience, avidity, skill and centrality to lifestyle. As such, each variable is examined individually.

These results suggest that relative to non-members, fishing club members typically have more years of fishing experience, fish more days in a year specifically for mako (avidity), are more skilled, hold more fishing magazine subscriptions (centrality to lifestyle) and give slightly more importance to mako fishing amongst other types of fishing (*Table 3.3)*. NSW anglers typically held more magazine subscriptions than Tas anglers; this is the only component of specialisation to vary between states of residence (*Table 3.3)*.

Table 3.3: Summary of information relating to the specialisation criteria of Australian mako anglers. Criteria include measures of experience, avidity, self-perceived skill level and centrality of fishing and mako fishing to the respondent's lifestyle. [a] = Self-perceived skill level: anglers rated themselves either less (0), equally (1) or more (2) skilled than other game fishers when targeting mako sharks. [b]= Compared to other types of fishing, respondents rated mako fishing as either: the only type of fishing they do (1), the most important kind of fishing they do (2), the second most important type of fishing they do (3) or one of many types of fishing (4). [c] = Compared to other outdoor activities, respondents rated fishing as either: the only outdoor activity they participate in (1), their most important outdoor activity (2), second most important outdoor activity (3) or one of many activities they participate in (4).

Specialisation parameter	**State / Club Member**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
Years of fishing experience	NSW	23.34	11.64	20	H = 0.9557	0.620		
	Vic	21.81	11.63	20				
	Tas	22.12	11.81	20				
	Club Member	25.16	12.18	25	W = 6888.5	0.002		
	Not Member	20.75	11.16	20				
During the last 12 months, how many days have you fished salt water, whether you caught anything or not?	NSW	58.71	49.59	50	H = 2.429	0.297		
	Vic	51.30	47.88	38				
	Tas	55.04	43.16	45.5				
	Club Member	55.93	41.72	42	W = 8199	0.319		
	Not Member	54.70	49.01	40				
During the last 12 months, how many days did you spend fishing for mako sharks, whether you caught any or not?	NSW	7.63	13.13	3	H = 4.427	0.109		
	Vic	7.15	6.43	5				
	Tas	6.96	5.80	5				
	Club Member	9.08	11.92	6	W = 7108.5	0.006		
	Not Member	6.05	5.65	4				
Self-perceived skill level. [a]	NSW	0.76	0.78	1	H = 2.4891	0.288		
	Vic	0.93	0.76	1				
	Tas	0.88	0.72	1				
	Club Member	1.19	0.74	1	W = 5377.5	<0.0001		
	Not Member	0.64	0.67	1				

Table 3.3 continued…

Specialisation parameter	State / Club Member	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Importance of mako fishing relative to other types of fishing. [b]	NSW	3.96	0.25	4	H = 3.404	0.182		
	Vic	3.86	0.45	4				
	Tas	3.90	0.42	4				
	Club Member	3.85	0.51	4	W = 9337.5	0.049		
	Not Member	3.95	0.27	4				
Importance of fishing relative to other outdoor activities. [c]	NSW	2.40	0.87	2	H = 3.4675	0.177		
	Vic	2.20	0.88	2				
	Tas	2.41	0.91	2				
	Club Member	2.32	0.89	2	W = 9081.5	0.636		
	Not Member	2.36	0.88	2				
How many subscriptions do you currently have to fishing related magazines?	NSW	0.76	0.82	1	H = 6.3665	0.041	NSW – Vic	1.000
	Vic	0.81	1.15	0			NSW – Tas	0.042
	Tas	0.72	1.67	0			Vic - Tas	0.377
	Club Member	0.88	1.09	1	W = 7428	0.014		
	Not Member	0.68	1.43	0				

Consumptive orientation

Factor analysis indicated that the components of consumptive orientation were suitable to be incorporated into their constituent scales evaluating the importance of keeping fish/makos, catching a trophy fish/mako, catching numbers of fish/mako and catching something. This was true for both general fishing activity (*Table 3.4*) and mako specific scales (*Table 3.5*). No significant differences were observed in any of the consumptive orientation dimensions between club membership or state of residence. In both general and specific scales the pursuit of a trophy fish was the factor with the highest agreement from anglers, followed by catching numbers of fish/mako sharks. Keeping the catch was the item with the lowest agreement for both scales. The mako specific scale prompted significantly less consumptive responses for three of the four domains when compared to the general fishing activities scale. Specifically, when anglers were targeting mako sharks, there was less agreement with the importance of keeping sharks, catching trophy sharks and catching more sharks compared to general fishing activities (*Table 3.6*).

*Table 3.4: Resulting factor analysis for satisfactions gained from general fishing. * = reverse coded so that higher numbers represent higher consumptive orientation. Responses are strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). CFA fit indices: $n = 260$, $\chi^2 = 37.786$, $P < 0.019$, $df = 22$, $CFI = 0.964$, $RMSEA = 0.053$, $SRMR = 0.060$).*

General Fishing	**Mean**	**SD**	**Standardised Factor Loading**	**z value**
Keeping Fish (α = 0.68)	*2.59*	*0.79*		
I usually eat the fish I catch.	3.73	1.12	0.514	8.586
I'm just as happy if I release the fish I catch.*	1.70	0.83	0.588	8.495
Within legal limits, I prefer to keep all the fish I catch.	2.34	1.08	0.864	9.149
Catching a Trophy Fish (α = 0.55)	*3.91*	*0.69*		
I would rather catch one big fish than many smaller fish.	3.62	1.11	0.508	6.756
I'm happiest when I catch a challenging fish.	4.56	0.61	0.315	5.421
I like to fish where I know I am most likely to catch a trophy-sized fish.	3.57	1.05	0.834	7.721
Catching Numbers of Fish (α = N/A)	*3.38*	*1.15*		
The more fish I catch the happier I am.	3.38	1.15	1.000	28.366
Catching Something (α = 0.66)	*2.72*	*1.01*		
I'm just as happy if I don't catch a fish.*	2.66	1.12	0.543	8.146
I'm not satisfied with a fishing trip unless I catch at least something.	2.79	1.22	0.903	8.146

*Table 3.5: Resulting factor analysis for satisfactions gained from general fishing. * = reverse coded so that higher numbers represent higher consumptive orientation. Responses are strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). CFA fit indices: n = 260, χ^2 = 14.959, P < 0.864, df = 22, CFI = 1.000, RMSEA = 0.000, SRMR = 0.039).*

Mako Fishing	**Mean**	**SD**	**Standardised Factor Loading**	**z value**
Keeping Mako (α = 0.76)	*2.16*	*0.87*		
I usually eat the mako sharks I catch.	2.88	1.34	0.540	8.490
I'm just as happy if I release the mako sharks I catch.*	1.69	0.85	0.665	8.368
Within legal limits, I prefer to keep all the makos I catch.	1.91	1.00	0.965	9.140
Catching a Trophy Mako (α = 0.66)	*3.53*	*0.83*		
I would rather catch one big mako than several small makos.	2.97	1.23	0.542	9.269
I'm happiest when I catch a challenging mako shark.	4.18	0.83	0.494	8.144
I like to fish where I know I am most likely to catch a trophy-sized mako.	3.43	1.13	0.884	10.169
Catching Numbers of Mako (α = N/A)	*2.96*	*1.11*		
The more mako sharks I catch the happier I am.	2.96	1.11	1.000	27.905
Catching a Mako (α = 0.67)	*2.71*	*0.98*		
I'm just as happy if I don't catch a mako.*	2.81	1.12	0.612	9.401
I'm not satisfied with a mako fishing trip unless I catch at least one mako.	2.61	1.15	0.830	9.401

Table 3.6: Comparison of factor values for general and specifically worded consumptive orientation scales. W = paired Wilcoxon test statistic.

Comparison of scales	**W**	**P**
Keeping fish / Keeping Mako	17339.5	<0.0001
Catching a trophy fish / mako	14929.5	<0.0001
Catching Numbers of fish / mako	8182	<0.0001
Catching something / Catching a mako	7787.5	0.788

Angler motivations

Club members rated the importance of motivations for targeting mako sharks similarly to non-members (*Table 3.7*) however there were some differences in motivations for keeping and/or releasing mako sharks. Specifically, that club members were more likely to release makos when trying to win tag and release based competitions (*Table 3.8*) and more likely to keep mako sharks when fishing for a trophy fish and trying to win weight based competitions (*Table 3.9*). By contrast, non-members were more likely to keep sharks due to their reportedly low overall catches throughout the year. Motivations for targeting mako sharks varied between states, with NSW anglers placing lower importance on the challenge of catching mako shark, the size of the shark, the quality of the flesh for eating and the satisfaction gained from weighing in a large shark than both Vic, and Tas anglers (*Table 3.7*). Vic and Tas anglers expressed more disagreement with releasing mako sharks because they do not like to eat them than did NSW anglers (*Table 3.8*). Tas anglers were also found to assign higher importance to the sport of catch-and-release fishing and lower importance to reaching bag limits as a motivation for release compared to Vic anglers (*Table 3.8*). Finally, NSW anglers rated fishing for food as a less important motivation for keeping captured mako sharks than both Vic and Tas anglers (*Table 3.9*).

Table 3.7: Summary information relating to an angler's motivations for fishing for mako sharks. Mean and median range is from 1 (Not at all important) to 5 (Very important) with 3 representing moderate importance.

Motivations for fishing for mako sharks	**State / Club Member**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
The challenge of catching a mako	NSW	3.75	0.98	4	H = 17.757	0.0001	NSW – Vic	0.0001
	Vic	4.35	0.82	5			NSW – Tas	0.005
	Tas	4.15	0.96	4			Vic – Tas	0.623
	Club Member	4.10	0.87	4	W = 8222.5	0.879		
	Not Member	4.06	1.01	4				
The large size of makos compared to other species	NSW	3.12	1.16	3	H = 7.886	0.019	NSW – Vic	0.022
	Vic	3.65	1.05	4			NSW – Tas	0.113
	Tas	3.44	1.25	4			Vic – Tas	1.000
	Club Member	3.37	1.05	3	W = 8601	0.420		
	Not Member	3.41	1.28	4				
The makos fighting qualities compared to other species	NSW	4.32	0.83	5	H = 0.413	0.814		
	Vic	4.41	0.79	5				
	Tas	4.33	0.85	5				
	Club Member	4.28	0.81	4	W = 9028.5	0.096		
	Not Member	4.41	0.83	5				
The thrill of seeing a mako jump	NSW	4.36	0.97	5	H = 1.304	0.521		
	Vic	4.48	0.88	5				
	Tas	4.41	0.75	5				
	Club Member	4.45	0.91	5	W = 7561	0.269		
	Not Member	4.40	0.82	5				
The high quality flesh of mako for eating	NSW	2.46	1.54	2	H = 36.099	<0.0001	NSW – Vic	<0.0001
	Vic	3.67	1.34	4			NSW – Tas	<0.0001
	Tas	3.76	1.23	4			Vic – Tas	1.000
	Club Member	3.34	1.54	4	W = 7916	0.703		
	Not Member	3.30	1.43	4				

Table 3.7 continued…

Motivations for fishing for mako sharks	**State / Club Member**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
The satisfaction gained from weighing in a large shark	NSW	1.59	1.10	1	H = 19.435	<0.0001	NSW – Vic	<0.0001
	Vic	2.45	1.37	2			NSW – Tas	0.044
	Tas	1.97	1.21	1			Vic – Tas	0.059
	Club Member	1.90	1.22	1	W = 8632	0.366		
	Not Member	2.06	1.30	1				
The chance to interact with amazing animals in their natural environment	NSW	4.20	0.90	4	H = 3.139	0.208		
	Vic	4.25	0.93	4				
	Tas	4.42	0.76	5				
	Club Member	4.38	0.82	5	W = 7406.5	0.178		
	Not Member	4.25	0.87	4				
They are the only game fishing species to target at certain times of the year	NSW	2.51	1.24	2	H = 0.799	0.671		
	Vic	2.72	1.42	3				
	Tas	2.64	1.32	3				
	Club Member	2.70	1.34	3	W = 7522.5	0.289		
	Not Member	2.54	1.32	2				

Table 3.8: Summary information relating to an angler's motivations for releasing mako sharks that they could have legally kept. Mean and median range is from 1 (Strongly Disagree) to 5 (Strongly Agree) with 3 representing "Neutral".

Motivations for releasing mako sharks	**State / Club Member**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
I don't like to eat mako shark	NSW	2.65	1.28	3	H = 21.302	<0.001	NSW – Vic	0.001
	Vic	1.88	0.87	2			NSW – Tas	<0.001
	Tas	1.84	0.92	2			Vic – Tas	1.00
	Club Member	2.06	1.09	2	W = 6586	0.681		
	Not Member	2.12	1.10	2				
I have already caught what I plan to eat	NSW	3.47	1.13	4	H = 3.776	0.151		
	Vic	3.71	1.18	4				
	Tas	3.78	1.05	4				
	Club Member	3.79	1.04	4	W = 5927	0.325		
	Not Member	3.62	1.16	4				
I have an interest in conservation fishing	NSW	4.33	0.76	4	H = 0.682	0.711		
	Vic	4.19	0.89	4				
	Tas	4.30	0.72	4				
	Club Member	4.29	0.78	4	W = 7079	0.807		
	Not Member	4.27	0.78	4				
I enjoy the sport of catch-and-release fishing	NSW	4.36	0.73	4	H = 6.882	0.032	NSW – Vic	0.079
	Vic	4.03	0.91	4			NSW – Tas	1.00
	Tas	4.36	0.73	4			Vic – Tas	0.049
	Club Member	4.34	0.70	4	W = 6733.5	0.399		
	Not Member	4.22	0.85	4				
I have reached my bag/possession limit	NSW	2.73	1.40	3	H = 7.318	0.025	NSW – Vic	0.074
	Vic	3.31	1.29	3			NSW – Tas	1.000
	Tas	2.74	1.41	3			Vic – Tas	0.037
	Club Member	2.81	1.48	3	W = 6178	0.351		
	Not Member	2.98	1.32	3				

Table 3.8 continued…

Motivations for releasing mako sharks	State / Club Member	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I am trying to win a tag and release based competition	NSW	3.16	1.25	3	H = 3.038	0.218		
	Vic	2.77	1.25	3				
	Tas	3.04	1.34	3				
	Club Member	3.57	1.22	4	W = 2416.5	<0.001		
	Not Member	2.45	1.11	2.5				

Table 3.9: Summary information relating to an angler's motivations for keeping mako sharks. Mean and median range is from 1 (Strongly Disagree) to 5 (Strongly Agree) with 3 representing "Neutral".

Motivations for keeping mako sharks	State / Club Member	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I believe the shark will not survive release	NSW	2.81	1.37	3	H = 2.907	0.233		
	Vic	3.19	1.42	3				
	Tas	2.90	1.45	3				
	Club Member	2.99	1.50	3	W = 6434.5	0.674		
	Not Member	2.92	1.37	3				
I am fishing for a trophy-sized shark	NSW	2.39	1.23	2	H = 4.293	0.116		
	Vic	2.67	1.16	3				
	Tas	2.28	1.17	2				
	Club Member	2.73	1.28	3	W = 4748	0.001		
	Not Member	2.20	1.06	2				
I am trying to win a weight based fishing competition	NSW	2.84	1.39	3	H = 0.941	0.624		
	Vic	2.62	1.14	2.5				
	Tas	2.65	1.28	3				
	Club Member	3.09	1.30	3	W = 3646.5	<0.001		
	Not Member	2.35	1.16	2				

Table 3.9 continued…

Motivations for keeping mako sharks	State / Club Member	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I am fishing for food [b]	NSW	3.03	1.32	3	H = 12.307	0.002	NSW – Vic	0.05
	Vic	3.58	1.18	4			NSW – Tas	0.001
	Tas	3.73	1.09	4			Vic - Tas	1.00
	Club Member	3.38	1.22	4	W = 6955.5	0.254		
	Not Member	3.54	1.21	4				
Whenever it is legal to do so	NSW	2.11	1.11	2	H = 5.608	0.060		
	Vic	2.58	1.21	2				
	Tas	2.24	1.17	2				
	Club Member	2.26	1.18	2	W = 6266	0.674		
	Not Member	2.33	1.18	2				
I don’t catch many mako sharks in a year [a]	NSW	3.02	1.27	3	H = 2.176	0.336		
	Vic	3.38	1.23	3				
	Tas	3.15	1.25	3				
	Club Member	2.96	1.37	3	W = 7325.5	0.023		
	Not Member	3.36	1.14	4				

Discussion

This study reveals a geographic difference in the catch-and-release behaviour of shortfin mako anglers coinciding with variation in the value of the species as a sport and table fish. Club membership was indicative of angler specialisation, however specialisation was not indicative of catch-and-release behaviour. These results reveal a disconnect between fishing club membership, specialisation and catch-and-release behaviour and show that where anglers reside has the greatest influence on catch-and-release behaviour indicating “cultural” differences exist between states.

Fishing club members in this study were more specialised than non-members, which is in agreement with previous studies (Gigliotti and Peyton, 1993; Fisher, 1997). However, there was no difference in the proportion of sharks released between club and non-club members, which contrasts previous studies that show higher specialisation anglers are expected to practise catch-and-release more frequently (Gigliotti and Peyton, 1993; Graefe and Ditton, 1997; Sutton, 2001). The overall portion of released sharks was approximately 70% and this was found to vary the most between states, with NSW anglers releasing the highest proportion of sharks (82.4%), followed by anglers from Tas (59.0%) and finally Vic (50.7%). Specialisation parameters did not vary much between these geographic groupings, indicating that variations in specialisation may not drive the decision to release mako sharks in this particular fishery. Motivations however, did vary geographically, which provides some insight into what may be driving the decisions to release sharks.

Anglers in this study were most likely to be full time trades persons, 100% of my sample was also male and the average age of respondents was 35 years. These demographics closely match those of other recreational and game fishing studies and reflect previous documentation of the recreational fishing sector being dominated by middle-aged, male trades persons (Wilde *et al.*, 1998; Henry and Lyle, 2003; Frijlink, 2011; Heard *et al.*, 2016). The wider fishing community certainly includes female game fishers (Henry and Lyle, 2003; Zischke *et al.*, 2012; Tracey *et al.*, 2013b; Heard *et al.*, 2016), the opinions and attitudes of which were absent from my sample as they did not submit any responses to this survey. While this does not necessarily impact the results greatly, it does exhibit some of the drawbacks associated with the self-selected sampling method; that is, very little control over the relative representation of demographic groups. Nonresponse bias can also influence results (Salz *et al.*, 2001) and it is possible that primarily the more specialised anglers or anglers who already had a passion for shark conservation would take the time to fill out this survey and as such, these results should be interpreted with this in mind. That is, these data are useful for identifying subgroups and varying attitudes amongst game fishers, however they are unlikely representative of the game fishing population as a whole.

Specialisation

My method for measuring specialisation was adapted from the scale presented in Sutton and Ditton (2001) and applied factor analysis in an attempt to confirm the existence and significance of the specialisation factors that were proposed in Sutton (2001). However, this approach revealed that each individual variable explained too much of the sample variance to be incorporated into a factor; hence, factor analysis was not used for examining specialisation in the interest of preserving data integrity and variables are examined separately.

On average, respondents had over 20 years of fishing experience, fished in salt water over 50 days each year and spent around seven days each year targeting mako sharks specifically. Comparing this to national and Tasmanian surveys of recreational fishers, it can be seen that most anglers in this study exhibit the avidity characteristics of a highly specialised group (Graefe, 1980; Ditton *et al.*, 1992; Salz *et al.*, 2001; Henry and Lyle, 2003; Lyle *et al.*, 2014). Previous studies have established a positive relationship between angler specialisation and the propensity to practice catch-and-release (Gigliotti and Peyton, 1993; Sutton, 2001). This is likely explained by the expectation that high specialisation anglers are more perceptive to resource disturbances and having invested more time and money into fishing will be more committed to wanting to preserve the resource for future use (Fisher, 1997; Salz *et al.*, 2001; Oh and Ditton, 2006). Overall, fishing for mako is an inherently specialised type of fishing that requires a substantial investment or commitment from the angler. It typically occurs in waters several kilometres offshore, requiring access to expensive vessels and some degree of experience in seamanship. The species is also often large and difficult to catch, requiring further knowledge and expense on specialised gears along with additional knowledge on locating and handling the animals. The willingness to pay (WTP) for fishing expenses and experiences has previously been found to be associated with high specialisation and increased release rates (Schuhmann and Schwabe, 2004; Oh and Ditton, 2006). Together, this information indicates that shortfin mako fishers, and likely other big-game fishing groups, are highly specialised relative to other fishers.

Generally club membership has been associated with higher angler specialisation and subsequently higher participation in catch-and-release fishing (Gigliotti and Peyton, 1993; Fisher, 1997; Graefe and Ditton, 1997). In this study 39% of the sample was comprised of club members and this proportion was roughly equal across states. Amongst the general population of fishers, however, club members are rare (around 5%), but their representation amongst game fishing anglers is higher (Henry and Lyle, 2003), as is evident in the current survey. The age and the extent of fishing experience of club members was higher than non-members within this sample, implying that more experienced fishers with a higher commitment to the activity are more likely to join fishing clubs. The self-perceived skill, the number of days fished for mako and the number of sharks caught was also significantly higher for individuals who were club members, which ties in with research that shows club-members tend to catch a higher proportion of larger, less common game species than non-members (Zischke *et al.*, 2012). This higher level of experience, skill and avidity attributed to club members indicates that they are indeed more specialised than non-members (Sutton, 2001), hence it was interesting that the percentage of sharks released did not reflect this specialisation.

Alongside the actual percentage of sharks that were released, the angler's "release philosophy" was considered to partially account for any bias effect that may arise in actual release percentages for those anglers who caught very few sharks. For example, if a single shark was caught the release rate can only be 0 or 100%; these binary measures do not explain how an angler might treat catches involving multiple sharks. Both release philosophy and the actual percentage of released sharks were consistent, providing confidence in the validity of responses. These measures show that club members rank as more specialised than non-members yet release the same proportion of sharks. One possible explanation for this is that pelagic shark fishing, along with other types of open-water game fishing, requires a high degree of commitment and specialisation as a minimum to participate in the activity. Sutton and Ditton (2001) suggested that experience may only be important to a point where it allows fishing to become a central part of the angler's lifestyle and hence, encourage them to engage in more resource conservative behaviours. Participants in this study possess both the specialisation and commitment required of offshore game fishing which has likely placed them beyond this threshold. Hence, the varying levels of specialisation between anglers in this study may just represent varying levels of 'high specialisation', with likely very few low specialised anglers present in the sample population.

Both measures of release proportion did vary significantly across states, with NSW anglers releasing the highest portion of their catch. This may be due in part to the higher diversity of game fishing species available to NSW anglers, and hence opportunities for resource substitution are more readily available (Shelby and Vaske, 1991; Fisher and Ditton, 1993; Sutton and Ditton, 2005; Rogers and Bailleul, 2015). Victorian anglers were those with the highest harvest proportion, which may relate to the group also reporting the lowest catch rates. Fishing effort and catch rates of walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*), and smallmouth bass (*Micropterus Dolomieui*) have previously been found to be significantly related to the harvest rates of these species (Hunt *et al.*, 2002). If Victorian shortfin mako anglers are not expecting to catch more mako sharks later in the year it may contribute to them being more willing to keep the first shark they catch.

Consumptive orientation

Unlike the variables related to specialisation, the components of consumptive orientation were well suited for use in factor analysis. Factors relating to the importance of keeping fish/makos, catching numbers of fish/makos, catching a trophy fish/makos and catching something/a mako shark were able to be explained by my data, which is consistent with a number of previous studies (Aas and Vittersø, 2000; Anderson *et al.*, 2007; Kyle *et al.*, 2007). None of these factors varied by state or club membership, indicating that overall, anglers who fished for mako in this study gained similar satisfactions from their fishing experiences.

A change in consumptive orientation was observed when general fishing activities were compared to mako fishing specifically. To my knowledge a comparison of this type has not been tested previously. The first three factors in my analysis (keeping the catch, catching a trophy and catching higher numbers) were significantly different, with only the importance of "catching something" staying constant when the statements were worded specifically for mako sharks. Catching a trophy was of greatest importance to anglers across both scales, while keeping fish was of least importance. Although these two factors seem to contradict each other it is important to note that the question relating to catching trophy fish makes no inference about the fate of the fish (kept or released). The main driver of reduced consumptive orientation in the “keeping” category was the statement “I usually eat the fish/mako I catch”, which moved from agreement in the general scale to disagreement in the mako specific scale. This result was somewhat expected due to the complexity involved in utilising mako as a food item. The size of the shark, the iconic perception of the species, its conservation status, the visual impact on bystanders often surrounding its slaughter and the flesh quality compared to other premium eating fish all likely play a part in the decreased desire for retention.

Motivations

Furthering the notion that game fishers in this study conform to a highly specialised fisher profile are the motivations that were rated with highest importance for targeting mako sharks: the thrill of seeing a mako jump, the sharks’ fighting qualities, the challenge of catching mako shark and the ability to interact with the animals in their natural environment; whereas the least important motivation was weighing the sharks in. An increased satisfaction gained from the experience of the catch has been found previously to be positively related to specialization and likely links with the higher resource dependency of these anglers and hence, their willingness to preserve it (Salz *et al.*, 2001). Additionally, the consumptive and catch related components of fishing are well established as being of less importance to the more specialised of fishers (Fedler and Ditton, 1986; Ditton *et al.*, 1992; Salz *et al.*, 2001).

Anglers from NSW rated the challenge of catching mako, the size of the species and quality of the sharks flesh for consumption as less important motivations for targeting the species relative to anglers from Vic and Tas. This may be due in part to Vic and Tas anglers having access to fewer gamefish species than are available to NSW anglers (Rogers and Bailleul, 2015) and as such, the shortfin mako are more highly valued as a target species in these southern states. The significantly lower importance given by NSW anglers to the quality of mako flesh as a motivation for targeting the species was the largest difference among motivations for fishing the species and reflects the greater importance of mako as a self-sourced food item for Vic and Tas anglers. Additionally, as shark meat is more commonly commercially caught sold in Vic and Tas than it is in NSW (AFMA, 2016a), shark has varying cultural importance as a food item between regions and demand is likely affected by the cultural norms of anglers from these regions. The diversity of alternative species in NSW may also contribute to an underlying culture of catch-and-release fishing, such as that seen in the NSW recreational marlin fishery (Zischke *et al.*, 2012). Social norms have been defined as “informal rules shared by groups or societies that guide behaviour and have positive and/or negative consequences that help make the behaviour more or less self-correcting” (Heywood, 2011). The participation in an essentially 100% catch-and-release sport fishery such as that of marlin in NSW may establish social and personal norms for these anglers, that in turn may translate to a higher propensity to practise catch-and-release across other iconic game fishing species such as shortfin mako (Heywood, 2011; Stensland *et al.*, 2013). NSW anglers also gave the lowest importance to the satisfaction gained from weighing a mako, however all states rated this component somewhere between ‘not at all important’ and ‘moderately important’ with Vic anglers closest to ‘moderately important’.

In relation to motivations for releasing sharks, the most agreement across groups was associated with an interest in conservation fishing and enjoyment in the sport of catch-and-release. Vic and Tas anglers expressed significantly more disagreement with releasing sharks because they don't like to eat mako shark, and significantly more agreement with retaining a shark because they are fishing for food than NSW anglers, indicating again that the shortfin mako's importance as a food item to these angler groups is a primary reason for its retention and highlights the culture of eating sharks in Vic and Tas. The differences in motivations between club members and non-members were predominantly linked to the statements that related to fishing competitions, which is unsurprising given that only registered club members may participate in most tournaments in Australia. Club members were more likely to release mako sharks when trying to win tag based competitions and more likely to keep mako sharks when fishing for trophies and trying to win weight based competitions than were non-members. This indicates that, at least for fishing club members, behaviours may be modified by incentives provided during fishing competitions; however, as only club members may participate in these competitions in Australia, a large section of the angler population will remain unaffected by efforts to modify behaviours through these methods.

Summary

Fishing club members were found to be relatively more specialised than non-members; however this variation in specialisation between members and non-members was not related to catch-and-release behaviour, indicating that all anglers who participated in this study showed a high degree of specialisation and resource dependency regardless of their affiliation with fishing clubs. The main difference in catch-and-release behaviour was observed between states, with NSW anglers reporting to release the highest proportion of their catch. This behaviour is primarily related to the varying value of shortfin mako as a sport fish and table fish between these regions and may be due to the increased opportunity for resource substitution available to NSW anglers and the established norms driven by current catch-and-release fisheries in that region. Increased participation in catch-and-release fishing may still be achieved to some degree in Vic and Tas by the provision of more desirable incentives to release sharks during fishing competitions. Norms established within fishing clubs may then spread to anglers that are not affiliated with fishing organisations. Future research should look into better understanding impediments to the adoption of catch-and-release fishing and how conservative norms may be developed for iconic species in an attempt to promote catch-and-release fishing across multiple species.

Chapter 4
Explaining Fishing Behaviours with Existing Beliefs on Sharks and Their Conservation

Very little is documented about the specific gears and methods that recreational anglers use to target sharks and little is known concerning the rationale behind these choices. In catch-and-release fisheries decreased animal welfare and post-release mortality can most commonly be linked to physical injuries associated with the gear used and the handling of the animal. Conservation behaviour as simple as adherence to responsible fishing techniques can help to minimise fishing mortality in many shark fisheries. However, public attitudes and perceptions can play a large part in how individuals participate in a fishery and as such, it is important to establish a standard of trust and communication between anglers, scientists and fisheries managers before any successful attempts at promoting this information can be made. This study aims to examine the gear choices and fishing preferences of Australian shortfin mako shark anglers and relate these to the angler's perceptions on the impacts of shark fishing, their opinions on sharks and shark populations, and their support for fisheries management. This was done in an effort to better understand the rationale behind the practices and choices that anglers make regarding their fishing behaviours. This study utilised a targeted web survey to obtain information regarding the current gears and methods used by recreational shortfin mako fishers and how these relate to the angler's perceptions on the impacts of recreational shark fishing, their opinions on sharks and shark populations, and their support for fisheries management. Information presented is based on the responses from 287 shortfin mako anglers distributed across south eastern Australia. Overall, game fishers have generally realistic and accurate perceptions about how their fishing behaviours and gear choices may affect the survival of released shortfin mako sharks. Selection of gear was shown to be determined largely by the fishing preference of the angler, with those practising catch-and-release more frequently using circle hooks more often. Geography also played a large part in determining the perceptions and behaviours of fishers with the largest differences in the opinion of respondents most commonly being noted between NSW and Tas. Respondents from NSW were also found to have the least support and trust for fisheries management. Most respondents did not acknowledge that their fishing behaviours were able to impact shark stocks, rather shifting all accountability onto commercial fisheries. Angler support for precautionary management suggests that a better understanding of the potential impacts of recreational fishing on shark stocks may assist in promoting greater accountability and responsible fishing practices amongst these resource users; however, improved communication between recreational fishers, management authorities and fisheries scientists is a necessary precursor to this step.

Introduction

Throughout the world, there now exists a large body of research concerning catch-and-release angling in recreational fisheries (see Arlinghaus *et al.* (2007a) for review). Although fishing methods and gears used, and the target species' susceptibility to post release mortality varies across fisheries, some general guidelines for improving catch welfare have been developed that apply to the vast majority of recreational fisheries (Cooke *et al.*, 2012). These guidelines include minimising angling duration and air exposure, using barbless hooks and avoiding angling during water temperature extremes or periods when target species are spawning (Cooke and Suski, 2005). In most instances, decreased animal welfare and post-release mortality can be linked to physical injuries associated with the gear used and the handling of the animal (e.g.: Muoneke and Childress (1994), Bartholomew and Bohnsack (2005), Chapter 2). The most common relationship in all of these studies is the association between post-release mortality and the occurrence of deep hooking (Cooke *et al.*, 2012). Deep hooking is characterised by hook penetration of sensitive tissues beyond the mouth cavity such as the oesophagus, gills and organs (Fobert *et al.*, 2009). This is an important issue when considering fishery effects on both bycatch and target species in recreational gamefish fisheries; particularly as many fish populations targeted by game fishers for either catch-and-release or consumption are often already affected by fishing pressures (Cooke *et al.*, 2016).

Deep hooking has been shown to significantly increase mortality rate in a wide variety of species (Bartholomew and Bohnsack, 2005; Reeves and Bruesewitz, 2007; Campana *et al.*, 2009; Epperly *et al.*, 2012; Kneebone *et al.*, 2013), with necropsy showing deep hooking to be associated with hook penetration of the pericardium (Kneebone *et al.*, 2013) and vital organs, such as the heart, liver and parts of the lower alimentary canal (Caruso, 2000; Borucinska *et al.*, 2001; Borucinska *et al.*, 2002). Hooking injuries can also lead to delayed mortality through starvation events caused by damaged oesophagi (Burns and Froeschke, 2012), while retained hooks can result in short term physiological perturbations (Fobert *et al.*, 2009) or lead to mortality over longer periods by causing systemic diseases (Borucinska *et al.*, 2001; Adams *et al.*, 2015). Although deep hooking events can be managed by the angler in different ways (either attempting to remove the hook, or leaving it in and cutting the line), the best course of action is always to reduce the likelihood of deep hooking from occurring in the first place (Fobert *et al.*, 2009).

The effect of hook type on hooking location and subsequent survival has been well documented in both commercial (Falterman and Graves, 2002; Carruthers *et al.*, 2009; Pacheco *et al.*, 2011; Epperly *et al.*, 2012) and recreational studies (Prince *et al.*, 2002; Skomal *et al.*, 2002; Aalbers *et al.*, 2004; Graves and Horodysky, 2008; Burns and Froeschke, 2012). Although exceptions exist, more often than not comparisons between standard J hooks and circle hooks reveal the latter to reduce deep hooking while increasing the survivorship of released individuals (Cooke and Suski, 2004; Bartholomew and Bohnsack, 2005; Graves and Horodysky, 2008; Mapleston *et al.*, 2008; Carruthers *et al.*, 2009; Burns and Froeschke, 2012; Epperly *et al.*, 2012). It should be noted that although circle hooks are better for fish welfare in the majority of instances, offsetting circle hooks can counteract their conservation benefits by increasing deep hooking and subsequent mortality (Cooke and Suski, 2004; Epperly *et al.*, 2012; Rice *et al.*, 2012). While some commercial operations are now required to use circle hooks as standard practice (AFMA, 2014), the overall frequency of their use in recreational fisheries is still unknown. In order to better understand the impacts of fishing on a particular species for which the efficacy of circle hooks to reduce deep hooking has been demonstrated, it is of particular importance to understand the gear currently used by recreational fishers and any factors that may influence the uptake of more responsible gears such as circle hooks.

Public attitudes and perceptions can play a large part in how individuals participate in a fishery (McClellan Press *et al.*, 2016). This concept is complicated further in the context of shark fisheries, where elements of fear and negativity may reduce public support for shark conservation or even incite opposition to it (Philpott, 2002; O'Bryhim, 2009). Additionally, the potential magnitude of recreational catches and the vulnerability of many shark species to fishing pressure may not be realised by anglers. This lack of recognition of impact could feed beliefs that there is currently no need for shark conservation measures at least amongst recreational resource users (Gray and Jordan, 2010; Bruce, 2014). Conservation behaviour as simple as adherence to recommended best-practice fishing techniques can help to minimise fishing mortality in some shark fisheries, however, even avid anglers with many years of fishing experience may not be familiar with these recommendations (McClellan Press *et al.*, 2016). Effective communication between anglers, scientists and fisheries managers is the first step in the dissemination of accurate information regarding responsible fishing methods, so it is important to establish a standard of trust and communication between these groups. Therefore the current perceptions and attitudes towards management must be understood before any attempts to move forward with cooperation from anglers can be made (Cardona and Morales-Nin, 2013).

In Australia, the shortfin mako shark (*Isurus oxyrinchus*) is targeted for both consumption and catch-and-release by recreational anglers. It is, however, prohibited to be retained if retrieved live during commercial operations. Furthermore, commercial operators are limited in the number of sharks they can legally retain each trip (Rogers *et al.*, 2015). Although bag limits for shark do apply to recreational anglers throughout Australia, the number of anglers fishing for shark, the frequency that they fish for shark, and hence, the total annual harvest attributed to recreational fishing is unknown and largely unmonitored. Although the status of Australian mako populations is unknown, the species has suffered dramatic declines across parts of its range due to fishing (Dulvy *et al.*, 2008; Ferretti *et al.*, 2008; Chang and Liu, 2009). Recognition that recreational harvests can parallel, and even exceed, commercial harvest in some fisheries (McPhee *et al.*, 2002; Post *et al.*, 2002; Cooke and Cowx, 2004) suggests that recreational anglers may impose a substantial portion of the fishing pressure on this species. As such, future management efforts should focus on working with recreational anglers to limit fishing mortality as much as possible. Foul-hooking of this species has been associated with mortality in both recreational and commercial fisheries and evidence exists to show that much of this may be prevented by the use of circle hooks (Chapter 2; Epperly *et al.*, 2012). A recent Australian survey indicated that approximately 55% of tournament anglers practice catch-and-release when targeting pelagic sharks, however less than half of these anglers reported using circle hooks (Heard *et al.*, 2016), which is likely to have implications for the survival of released individuals. Additionally, no published information is currently available for gear use by non-tournament fishers, which likely constitutes the majority of the users of this resource (Chapter 3).

This study aims to examine the gear choices and fishing preferences of Australian shortfin mako shark anglers and relate these to the angler's perceptions on the impacts of shark fishing, their opinions on sharks and shark populations, and their support for fisheries management in an effort to better understand the rationale behind the practices and choices that anglers make regarding their fishing behaviours. These responses were compared between three different states as each Australian state manages their recreational fisheries independently and it is likely that this will influence angler attitudes and practices. Additionally, club membership and whether anglers typically retain or release their shark catch (referred to throughout as 'fishing preference') have been used as additional grouping factors to compare these behaviours and perceptions in an effort to better understand the origin of some practices and beliefs.

Methods

Distribution

A structured web-based questionnaire was designed and distributed using the online platform 'Survey Monkey'. The questionnaire was pilot tested with a small group of experienced recreational fishers to refine questionnaire structure, flow and address potential misunderstanding or ambiguities in the questions prior to its implementation. The final questionnaire was made accessible to the public between May – September 2014. It was promoted via various game-fishing web forums (three based in Tasmania, two in Victoria and two in New South Wales), social media pages associated with game fishing and participating game fishing clubs (promotional information and instructions were sent to club presidents and secretaries belonging to all Game Fishing Association of Australia (GFAA) registered clubs in the three states. The survey was also promoted by game fishing celebrities through social media. The chance to win a game fishing reel was provided to respondents as incentive to complete the questionnaire.

Questionnaire design

The self-administered questionnaire was separated into seven sections; 'catch-and-release preferences', 'specialisation and consumptive orientation', 'gear use and perception of circle hooks', 'perceptions of sharks and shark survival', 'attitudes towards management', 'fishing behaviour and motivations' and 'demographics'. The four of these relevant to the current study are explained in more detail below.

Gear Use and Perceptions on Circle Hooks

This section sought information about the gears that anglers selected when they expected to release or retain sharks. Respondents were asked a filtering question “Please indicate which of the following best describes you: 1. I never aim to release sharks, 2. I aim to keep and release sharks depending on the situation, 3. I never aim to keep sharks”. Those who answered “1” were only asked how often they used certain gears when targeting sharks to keep, those who answered “3” were offered the same questions in relation to catching sharks to be released and those who answered “2” were offered both sets of questions. Responses available ranged along a five point scale ranging from “Never” to “Always”.
The section also evaluated perceptions regarding circle hooks. Anglers were asked to rate their agreement with 13 statements about circle hooks along a five point scale ranging from “Strongly Disagree” to “Strongly Agree”, a sixth option for “Unsure/Don’t Know” was also offered, however these responses were removed prior to analysis.

Perceptions of Sharks and Shark Survival

This section asked respondents whether they believed that under current fishing pressures, Australian shortfin mako stocks were decreasing, stable or increasing. Respondents were also asked to rate what they believed the likelihood of survival would be for a mako shark caught and released under certain conditions. Responses were rated on a five-point scale ranging from “almost certainly survive” to “almost certainly won’t survive”, with an additional category for the response “unsure/don’t know”, which was subsequently excluded from the analysis. Respondents were also asked to rate their level of agreement with general statements about sharks. Responses were structured around a five point Likert-type scale ranging from “strongly agree” to “strongly disagree”, again with an additional category for the response “unsure/don’t know”, which was subsequently excluded from the analysis.

Attitudes Towards Management

This section asked respondents to report on how they felt about various management regulations by rating their agreement with seven hypothetical management policies based on a five-point scale ranging from “Strongly Disagree” to “Strongly Agree”. This was followed up by investigating potential reasons that management regulations may not be adhered to by rating agreement with eight statements, responses for “unsure/don’t know” were removed prior to analysis. Finally, agreement was rated for eight statements that reflect the personal beliefs of anglers about fisheries management.

Demographics

Basic demographic information including the angler’s state of residence and whether or not they belonged to a fishing club was collected for each respondent for use as grouping variables in the analysis.

Analysis

All statistical analyses were conducted using R (R Core Team, 2014).

Factor Analysis

Two main frameworks were developed that examined beliefs about circle hook use for shortfin mako shark and subsequently tested for fit with my data using confirmatory factor analysis (CFA). The first framework was a four factor model that tested four observed components of circle hook use; beliefs that circle hooks are good for catch welfare, are hard to use, hinder catch rates and that offsetting circle hooks is beneficial. The second model was developed based on results suggested by running an Exploratory Factor Analysis (EFA). The number of factors to specify in the EFA was first identified using Principal Components Analysis (PCA), based on eigenvalues exceeding one. A three factor model was then tested using three different rotations, with only rotations resulting in a factor solution with simple structure being retained. Any items that were not shown to have acceptable loadings (>0.3) on any factors were removed and the analysis re-run without them.

The fit of these two frameworks to the data was then investigated using CFA (Anderson *et al.*, 2007; Kyle *et al.*, 2007), with an acceptable model fit based on criteria recommended by Hu and Bentler (1999) and Schreiber *et al.* (2006). CFA is widely used for examining relationships between Likert type variables, such as those derived from the current survey (Flora and Curran, 2004). Prior to the CFA, the scale was tested for multivariate normality using the MVN package (Korkmaz *et al.*, 2014) and subsequently Diagonally Weighted Least Squares (DWLS) was chosen as the estimation method for use in the CFA (Mindrila, 2010). Models that were shown to have an unacceptable fit to the data were discarded. The CFA model was carried out using the Lavaan package for R (Rosseel, 2012). Factor loadings, z-values and measure of internal consistency (Cronbach's alpha or Spearman's coefficient where appropriate) are presented.

Comparisons between groups

The difference in gear used when anglers were aiming to keep or release sharks was examined using paired Wilcox tests. Gear use, perceptions on sharks and management were then compared between club members and non-members using independent sample Mann-Whitney U tests and between states using Kruskall-Wallis H tests as recommended by Lantz (2013) for the analysis of non-normal data. A third grouping, "fishing preference" was created by collapsing the two release oriented and two retain oriented responses from the variable "release philosophy" described in Chapter 3. The resulting variable was also used to compare angler subgroups using Kruskall-Wallis tests. Significant results from Kruskal-Wallis tests were followed up by pairwise comparisons with p values adjusted using the Bonferroni-Dunn method (Dunn, 1964; Pohlert, 2014).

Results

Gear use and effects on shark survival

The prevalence of gears used when sharks were targeted for retention was significantly different to those used when sharks were targeted for release. For instance, J hooks were more commonly used when retaining sharks, while circle hooks more commonly used when releasing sharks. Tail ropes were mostly used when targeting sharks for retention and rarely used when releasing sharks. A tag pole was almost never used when anglers aimed to retain sharks, whereas a gaff was mostly used in this instance. A gaff was also rarely used by anglers who were practicing catch-and-release (*Table 4.1*).

Table 4.1: Comparison of the prevalence of gear usage when anglers aimed to either retain or release mako sharks. Mean and median range is based on response codes for always (1), mostly (2), sometimes (3), rarely (4) and Never (5). n = 186 for anglers retaining mako sharks and n = 223 for angler releasing mako sharks.

Gear used when catching and:	**Retaining Sharks**			**Releasing Sharks**			**Wilcox**	
	Mean	**SD**	**Median**	**Mean**	**SD**	**Median**	**V**	**P**
J hooks	3.18	1.50	3	3.61	1.36	4	1451	<0.0001
J hooks (offset)	3.83	1.22	4	4.14	0.98	4	958	<0.0001
Circle hooks	3.17	1.30	3	2.81	1.26	2	329	0.0004
Circle hooks (offset)	3.66	1.28	4	3.48	1.32	4	201	0.0039
Tail ropes	1.85	1.08	2	3.56	1.42	4	8642	<0.0001
Tagging Pole	4.47	0.98	5	3.13	1.57	3	109	<0.0001
Gaff	1.84	1.16	1	4.05	1.23	5	10248	<0.0001

With a few exceptions, there was no significant difference in gear use between state, club membership and fishing habit groups. Exceptions include anglers from NSW who reported more frequent use of circle hooks for catch-and-release fishing than anglers from Vic and Tas. Anglers who released most of their catch also reported a higher frequency of circle hook use during catch-and-release fishing compared to anglers who released less of their catch (*Table 4.2*). Anglers who kept most of their catch were significantly more likely to use J hooks during catch-and-release fishing. Non-club members used offset J hooks less commonly than club members for catch-and-release, although both groups used this gear rarely. A tag pole was mostly used by club members and rarely used by non-members. When catch and retain fishing, no significant differences in gear use were reported between groups (*Table 4.3*); however, non-members did appear to utilise circle hooks more frequently than club members (P = 0.053).

Table 4.2: Summary of the prevalence of gear usage by anglers when catching and releasing sharks. Results are separated by state, club membership and typical fishing behaviour. Mean and median range is based on response codes for always (1), mostly (2), sometimes (3), rarely (4) and Never (5).

Catch-and-release Gear	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
J hooks	NSW	3.93	1.21	4	H = 5.284	0.071		
	Vic	3.56	1.35	4				
	Tas	3.41	1.44	4				
	Club Member	3.42	1.35	4	W = 6923.5	0.056		
	Not Member	3.75	1.35	4				
	Release Most	3.74	1.34	4	H = 8.057	0.018	Release – Equal	1.000
	Equal	3.56	1.42	4			Release – Keep	0.014
	Keep Most	3.11	1.31	3			Equal – Keep	0.375
J Hooks (offset)	NSW	4.16	0.99	4	H = 1.083	0.582		
	Vic	4.25	0.91	4				
	Tas	4.07	1.02	4				
	Club Member	3.95	1.05	4	W = 7165	0.012		
	Not Member	4.28	0.90	5				
	Release Most	4.16	0.94	4	H = 1.113	0.573		
	Equal	4.22	1.05	5				
	Keep Most	4.00	1.09	4				
Circle Hooks	NSW	2.35	1.03	2	H = 11.804	0.003	NSW – Vic	0.044
	Vic	2.93	1.29	2			NSW – Tas	0.003
	Tas	3.05	1.33	3			Vic – Tas	1.000
	Club Member	2.87	1.20	3	W = 5678	0.424		
	Not Member	2.76	1.30	2				
	Release Most	2.63	1.21	2	H = 10.599	0.005	Release – Equal	0.072
	Equal	3.22	1.31	3			Release – Keep	0.021
	Keep Most	3.26	1.29	3			Equal – Keep	1.000

Table 4.2 continued…

Catch-and-release Gear	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
Circle Hooks (offset)	NSW	3.43	1.24	3				
	Vic	3.38	1.40	4	H = 1.708	0.426		
	Tas	3.64	1.31	4				
	Club Member	3.61	1.29	4	W = 5509	0.245		
	Not Member	3.39	1.34	3				
	Release Most	3.41	1.31	3				
	Equal	3.52	1.48	4	H = 2.732	0.255		
	Keep Most	3.79	1.26	4				
Tail Rope	NSW	3.74	1.25	4				
	Vic	3.25	1.52	3	H = 4.090	0.129		
	Tas	3.69	1.44	4				
	Club Member	3.68	1.37	4	W = 5617	0.3499		
	Not Member	3.48	1.46	4				
	Release Most	3.68	1.36	4				
	Equal	2.93	1.57	3	H = 5.698	0.058		
	Keep Most	3.50	1.48	4				
Tag Pole	NSW	2.96	1.60	3				
	Vic	3.20	1.53	3	H = 1.069	0.586		
	Tas	3.19	1.60	3				
	Club Member	2.16	1.29	2	W = 9603	<0.0001		
	Not Member	3.82	1.39	4				
	Release Most	2.98	1.58	3				
	Equal	3.37	1.60	4	H = 4.812	0.090		
	Keep Most	3.55	1.46	4				

Table 4.2 continued…

Catch-and-release Gear	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Gaff	NSW	4.03	1.11	4				
	Vic	3.82	1.45	5	H = 4.701	0.095		
	Tas	4.27	1.12	5				
	Club Member	4.04	1.23	5	W = 6135.5	0.836		
	Not Member	4.06	1.23	5				
	Release Most	4.16	1.09	5				
	Equal	3.96	1.29	4	H = 1.667	0.435		
	Keep Most	3.66	1.63	5				

Table 4.3: Summary of the prevalence of gear usage by anglers when catching and retaining sharks. Results are separated by state, club membership and typical fishing behaviour. Mean and median range is based on response codes for always (1), mostly (2), sometimes (3), rarely (4) and Never (5).

Catch and Retain Gear	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
J hooks	NSW	3.51	1.48	4	H = 2.974	0.226		
	Vic	3.02	1.38	3				
	Tas	3.14	1.56	3				
	Club Member	2.97	1.49	3	W = 4714.5	0.117		
	Not Member	3.32	1.49	4				
	Release Most	3.32	1.56	4	H = 3.899	0.142		
	Equal	3.08	1.47	3				
	Keep Most	2.82	1.27	3				
J Hooks (offset)	NSW	3.59	1.33	4	H = 1.718	0.424		
	Vic	3.97	1.10	4				
	Tas	3.84	1.26	4				
	Club Member	3.64	1.26	4	W = 4803.5	0.063		
	Not Member	3.96	1.18	4				
	Release Most	3.83	1.22	4	H = 0.237	0.888		
	Equal	3.92	1.23	4				
	Keep Most	3.79	1.26	4				
Circle Hooks	NSW	3.08	1.35	3	H = 1.069	0.586		
	Vic	3.10	1.24	3				
	Tas	3.29	1.31	3				
	Club Member	3.39	1.17	3	W = 3483.5	0.053		
	Not Member	3.03	1.36	3				
	Release Most	3.08	1.29	3	H = 4.512	0.105		
	Equal	3.00	1.30	3				
	Keep Most	3.56	1.27	3				

Table 4.3 continued…

Catch and Retain Gear	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Circle Hooks (offset)	NSW	3.67	1.13	4	H = 4.103	0.129		
	Vic	3.41	1.38	3				
	Tas	3.86	1.24	4				
	Club Member	3.75	1.23	4	W = 3912	0.470		
	Not Member	3.59	1.31	4				
	Release Most	3.64	1.26	4	H = 0.542	0.763		
	Equal	3.54	1.36	4				
	Keep Most	3.77	1.29	4				
Tail Rope	NSW	1.95	1.12	2	H = 0.445	0.801		
	Vic	1.88	1.13	2				
	Tas	1.80	1.04	1				
	Club Member	1.71	0.96	1	W = 4610.5	0.178		
	Not Member	1.95	1.15	2				
	Release Most	1.92	1.11	2	H = 5.009	0.082		
	Equal	1.38	0.57	1				
	Keep Most	1.95	1.17	2				
Tag Pole	NSW	4.28	1.10	5	H = 4.812	0.090		
	Vic	4.36	1.09	5				
	Tas	4.64	0.83	5				
	Club Member	4.49	0.92	5	W = 4152	0.973		
	Not Member	4.46	1.02	5				
	Release Most	4.43	1.00	5	H = 1.589	0.452		
	Equal	4.65	0.75	5				
	Keep Most	4.49	1.07	5				

Table 4.3 continued…

Catch and Retain Gear	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Gaff	NSW	1.85	1.06	1	H = 3.053	0.217		
	Vic	1.61	0.95	1				
	Tas	1.99	1.28	2				
	Club Member	1.72	1.09	1	W = 4612.5	0.170		
	Not Member	1.93	1.20	2				
	Release Most	2.00	1.25	2	H = 5.469	0.065		
	Equal	1.58	0.95	1				
	Keep Most	1.54	0.88	1				

Perceptions on circle hooks

Results from the four factor model (beliefs that circle hooks are good for catch welfare, are hard to use, hinder catch rates and that offsetting circle hooks is beneficial) revealed an unacceptable model fit based on SRMR value (CFA fit indices: n = 182, $\chi 2$ = 95.843, P < 0.002, df = 59, CFI = 0.971, RMSEA = 0.059, SRMR = 0.089).

A three factor model was developed using EFA with the "promax" rotation, this model rated angler's agreement with the proposed benefits of circle hook use, the ability of circle hooks to hinder catch rates and their general preference for using them when fishing. The model yielded an acceptable fit with my data when tested using CFA (*Table 4.4*) and shows that anglers agreed with the proposed benefits of using circle hooks (particularly those relating to improved catch welfare), while disagreeing with the proposed drawbacks. These three factors do not significantly vary between states or club members. However, the factor "*I don't like using circle hooks*" did vary by fishing preference, (H = 8.604, P = 0.014; $P_{(Release – Equal)}$ = 0.395, $P_{(Release – Keep)}$ = 0.019, $P_{(Equal – Keep)}$ = 1.000), with anglers who release most of their catch disagreeing with this factor (mean = 2.02, SD = 0.84, med = 2) significantly more than anglers who keep most of their catch (mean = 2.52, SD = 0.94, med = 3).

Effect on survival

Collectively, anglers assigned greater chance of survival to sharks that had been on the line for a long time, had external injuries from the trace and those that had been brought on deck compared with sharks that were bleeding heavily, non-responsive and those that had been gaffed. Some perceptions on shark survival varied by state with NSW anglers rating the likelihood of a gill-hooked shark surviving after release closer to 50/50 than both Vic and Tas anglers, who rated the item closer to "likely won't survive" (*Table 4.5*). Anglers from Tasmania also rated the likelihood of survival as "will likely survive" for a shark that had line wrapped around its tail causing it to be dragged backwards for a period, both NSW and Vic anglers rated this item closer to "likely won't survive". Club members also thought that sharks subjected to this treatment would be more likely to survive than non-members did. Additionally, club members were more likely to expect a shark to survive long fight times compared to non-members.

Table 4.4: Resulting factor analysis featuring angler's perceptions on circle hook use. Mean range is based on response codes for strongly disagree (1), disagree (2), neutral (3), agree (4) and strongly agree (5). CFA fit indices: n =182, χ^2 = 24.895, P = 0.978, df = 41, CFI = 1.000, RMSEA = 0.000, SRMR = 0.054).

Best Model	**Mean**	**SD**	**Standardised Factor Loading**	**z value**
Circle hook use has benefits (α = 0.80)	*4.01*	*0.71*		
Using circle hooks, rather than J hooks, increases the likelihood of a shark surviving once released.	4.22	0.95	0.825	13.551
Use of circle hooks decreases foul hooking in sharks, including gut hooks.	4.18	0.91	0.708	11.836
Circle hooks cause less damage to the shark compared to J hooks.	4.12	0.99	0.723	12.293
Using circle hooks, rather than J hooks, reduces the chance of dropping a shark once it is hooked.	3.63	1.03	0.576	11.149
I know how to use circle hooks correctly when fishing for sharks.	3.88	0.89	0.458	10.223
Circle hooks hinder catch rates (α = 0.88)	*2.46*	*0.91*		
Using circle hooks decreases the likelihood of catching a shark.	2.20	0.99	0.687	14.839
Using circle hooks decreases catch rates.	2.40	1.05	0.769	15.651
Using circle hooks decreases hook-up rates.	2.57	1.07	0.952	17.878
Using circle hooks makes it harder to hook-up.	2.67	1.09	0.841	16.688
I don't like using circle hooks (α = 0.84)	*2.14*	*0.89*		
Using circle hooks makes fishing for makos too hard compared to using J hooks.	2.30	0.98	0.881	11.996
Using circle hooks makes fishing less enjoyable.	1.98	0.94	0.824	11.996

Table 4.5: Summary of angler's perceptions on the likelihood of shark survival under different circumstances of capture; information is separated by state, club membership and typical fishing behaviour. Mean and median range is based on response codes for almost certainly survive (1), likely to survive (2), 50/50 chance (3), likely won't survive (4) and almost certainly won't survive (5). Responses for "unsure/don't know" were omitted prior to analysis.

Situation	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
It is hooked in the gut or throat.	NSW	3.08	0.98	3				
	Vic	3.45	0.97	3	H = 3.358	0.187		
	Tas	3.26	0.95	3				
	Club Member	3.18	0.97	3	W = 6420.5	0.215		
	Not Member	3.33	0.98	3				
	Release Most	3.21	0.93	3				
	Equal	3.27	0.92	3	H = 1.581	0.454		
	Keep Most	3.49	1.17	3				
It is hooked in the gills.	NSW	3.25	0.96	3			NSW – Vic	0.008
	Vic	3.74	0.89	4	H = 8.988	0.011	NSW – Tas	0.276
	Tas	3.52	0.95	4			Vic - Tas	0.346
	Club Member	3.47	0.88	3	W = 6111	0.487		
	Not Member	3.54	1.00	4				
	Release Most	3.44	0.95	3				
	Equal	3.65	0.89	4	H = 2.692	0.260		
	Keep Most	3.69	0.98	4				
It is bleeding heavily.	NSW	3.78	0.93	4				
	Vic	4.10	0.81	4	H = 3.792	0.150		
	Tas	3.89	0.89	4				
	Club Member	3.80	0.85	4	W = 6764.5	0.054		
	Not Member	4.00	0.91	4				
	Release Most	3.87	0.89	4				
	Equal	3.96	0.77	4	H = 2.183	0.336		
	Keep Most	4.08	0.94	4				

Table 4.5 continued…

Situation	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
It has been on the line for a long time.	NSW	2.73	0.81	3	H = 1.766	0.414		
	Vic	2.90	0.96	3				
	Tas	2.73	1.00	2.5				
	Club Member	2.59	0.85	4	W = 7106	0.004		
	Not Member	2.91	0.97	3				
	Release Most	2.72	0.90	3	H = 2.071	0.355		
	Equal	2.73	0.87	3				
	Keep Most	3.03	1.09	3				
Its tail is wrapped in the trace and it is pulled in backwards.	NSW	3.41	1.14	3	H = 12.659	0.002	NSW – Vic	1.000
	Vic	3.42	1.30	3			NSW – Tas	0.007
	Tas	2.87	1.14	3			Vic – Tas	0.010
	Club Member	2.96	1.09	3	W = 6875.5	0.011		
	Not Member	3.36	1.15	3				
	Release Most	3.20	1.15	3	H = 0.036	0.982		
	Equal	3.19	1.06	3				
	Keep Most	3.17	1.17	3				
Its body is cut by the trace.	NSW	2.48	0.98	2	H = 0.843	0.656		
	Vic	2.50	0.93	2				
	Tas	2.58	0.88	2				
	Club Member	2.35	0.87	2	W = 6679.5	0.146		
	Not Member	2.65	0.94	3				
	Release Most	2.45	0.92	2	H = 2.878	0.237		
	Equal	2.73	0.87	3				
	Keep Most	2.68	0.84	2.5				

Table 4.5 continued…

Situation	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
It appears non-responsive when bought boat-side.	NSW	3.65	1.06	4				
	Vic	3.81	0.92	4	H = 4.869	0.088		
	Tas	3.44	0.98	3				
	Club Member	3.64	0.96	4	W = 5584.5	0.799		
	Not Member	3.60	1.03	4				
	Release Most	3.64	1.03	4				
	Equal	3.54	0.90	3	H = 0.632	0.729		
	Keep Most	3.59	0.94	3				
It is bought on deck before release.	NSW	2.66	0.98	3				
	Vic	2.45	0.72	2	H = 2.765	0.251		
	Tas	2.73	0.95	3				
	Club Member	2.55	0.87	2	W = 6248	0.228		
	Not Member	2.70	0.92	3				
	Release Most	2.65	0.91	3				
	Equal	2.65	0.63	3	H = 0.747	0.689		
	Keep Most	2.58	1.03	2				
A gaff has been used on the shark to control it.	NSW	3.63	1.01	4				
	Vic	3.65	0.95	4	H = 2.747	0.253		
	Tas	3.85	1.01	4				
	Club Member	3.81	1.02	4	W = 5031	0.310		
	Not Member	3.69	0.98	4				
	Release Most	3.78	1.01	4				
	Equal	3.67	0.92	4	H = 1.062	0.588		
	Keep Most	3.62	1.00	4				

Perceptions on sharks and threats to shark populations

Respondents expressed strongest disagreement with the statement "Outside of fishing, I believe mako sharks are a danger to people" followed by the statements "Mako shark populations are able to recover quickly from overfishing" and "I believe my personal fishing activities can have an impact on mako shark stocks". Whereas, the greatest agreement was associated with the statements "I would not fish for mako sharks if I thought it was not sustainable" and "I regularly take steps to minimise my impact on shark stocks" (*Table 4.6*).

Significant differences in perceptions existed between states for the statements "I believe my personal fishing activities can have an impact on mako shark stocks" and "I believe recreational fishing can have an impact on mako shark stocks", with NSW respondents expressing the greatest level of disagreement with both statements. Anglers who generally retained their catch were also significantly more likely to view mako sharks solely as food items relative to anglers who practised catch-and-release fishing either some, or all of the time. NSW respondents expressed the greatest agreement of all states with the statement "I regularly take steps to minimise my impact on shark stocks", while anglers who released most of their shark catch expressed significantly more agreement with this statement than anglers who retained most of their shark catch. No significant differences of opinion were evident between club members and non-members (*Table 4.6*).

Anglers indicated that they believed the most serious threat to mako shark populations was commercial fishing bycatch and discards. Comparatively, recreational fishing was rated the least serious threat to mako shark populations by anglers, followed by global warming. Tas anglers rated recreational fishing significantly more of a threat to mako populations relative to both Vic and NSW anglers. Club members assigned a significantly higher threat rating to commercial fishing activities and a significantly lower threat rating to global warming relative to non-members (*Table 4.7*).

*Table 4.6: Rated agreement with statements relating to perceptions of mako sharks, mean and median values are based on response codes for strongly agree (1), agree (2), neutral (3), disagree (4) and strongly disagree (5). * Stocks are decreasing (1), stable (2) or increasing (3), answers for "unsure" (n = 52) were omitted.*

Statement	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
Outside of fishing, I believe mako sharks are a danger to people	NSW	4.24	0.93	4				
	Vic	4.40	0.80	5	H = 3.856	0.146		
	Tas	4.46	0.86	5				
	Club Member	4.34	0.89	5	W = 6190	0.733		
	Not Member	4.38	0.88	5				
	Release Most	4.35	0.92	5				
	Equal	4.54	0.65	5	H = 0.804	0.669		
	Keep Most	4.33	0.86	5				
I only see mako sharks as a source of sport or food	NSW	3.30	1.44	3				
	Vic	3.26	1.29	3	H = 0.219	0.896		
	Tas	3.22	1.27	3				
	Club Member	3.17	1.37	3	W = 6369.5	0.422		
	Not Member	3.33	1.29	3				
	Release Most	3.37	1.33	4			Release – Equal	1.000
	Equal	3.50	1.30	4	H = 10.131	0.006	Release – Keep	0.007
	Keep Most	2.67	1.15	3			Equal – Keep	0.035
Mako shark populations are able to recover quickly from overfishing	NSW	3.81	1.09	4			NSW – Vic	
	Vic	3.88	0.90	4	H = 0.044	0.978	NSW – Tas	
	Tas	3.91	0.91	4			Vic – Tas	
	Club Member	3.82	0.98	4	W = 4196.5	0.483		
	Not Member	3.91	0.94	4				
	Release Most	3.93	0.98	4				
	Equal	3.91	0.61	4	H = 3.840	0.146		
	Keep Most	3.57	1.03	3				

Table 4.6 continued…

Statement	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I would not fish for mako sharks if I thought it was not sustainable	NSW	2.09	0.99	2				
	Vic	2.00	1.06	2	H = 1.376	0.503		
	Tas	1.89	0.84	2				
	Club Member	1.94	0.89	2	W = 6087.5	0.841		
	Not Member	2.00	0.99	2				
	Release Most	1.94	0.96	2				
	Equal	2.15	1.05	2	H = 1.434	0.488		
	Keep Most	2.00	1.86	2				
I believe my personal fishing activities can have an impact on mako shark stocks	NSW	3.91	1.14	4			NSW – Vic	0.009
	Vic	3.29	1.21	3.5	H = 12.690	0.002	NSW – Tas	0.004
	Tas	3.30	1.24	4			Vic – Tas	1.000
	Club Member	3.61	1.27	4	W = 5239.5	0.179		
	Not Member	3.41	1.20	4				
	Release Most	3.46	1.28	4				
	Equal	3.68	0.90	4	H = 0.273	0.873		
	Keep Most	3.49	1.24	4				
I believe recreational fishing can have an impact on mako shark stocks	NSW	3.28	1.41	4			NSW – Vic	0.330
	Vic	2.88	1.18	3	H = 7.693	0.021	NSW – Tas	0.017
	Tas	2.69	1.18	2			Vic – Tas	1.000
	Club Member	3.05	1.29	3	W = 5032	0.160		
	Not Member	2.81	1.27	2				
	Release Most	2.92	1.30	3				
	Equal	3.08	1.26	3	H = 0.975	0.614		
	Keep Most	2.74	1.22	2				

Table 4.6 continued…

Statement	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I regularly take steps to minimise my impact on shark stocks	NSW	1.85	0.87	2	H = 10.010	0.007	NSW – Vic	0.005
	Vic	2.39	1.07	2			NSW – Tas	0.158
	Tas	2.13	0.95	2			Vic – Tas	0.421
	Club Member	2.13	1.01	2	W = 5955	0.923		
	Not Member	2.10	0.95	2				
	Release Most	1.89	0.85	2	H = 30.856	<0.0001	Release – Equal	0.152
	Equal	2.19	0.63	2			Release – Keep	<0.0001
	Keep Most	2.95	1.17	3			Equal – Keep	0.079
In your opinion, do you believe that under current fishing pressures the number of mako sharks in Australian waters is:*	NSW	2.02	0.60	2	H = 0.652	0.722		
	Vic	2.04	0.54	2				
	Tas	1.96	0.61	2				
	Club Member	2.09	0.57	2	W = 3335.5	0.069		
	Not Member	1.93	0.59	2				
	Release Most	1.99	0.60	2	H = 3.482	0.175		
	Equal	2.22	0.65	2				
	Keep Most	1.90	0.47	2				

Table 4.7: Perceived threats to mako shark populations as rated by shortfin mako shark anglers; mean and median ranges are based on response codes for Not a threat at all (1), Slight threat, should be monitored (2), Somewhat of a threat, current management is effective (3), A threat, needs better management (4), A serious threat, large changes are needed (5). Answers for "unsure/don't know" were omitted prior to analysis.

Proposed Regulation	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
Recreational fishing	NSW	1.86	0.89	2	H = 12.955	0.002	NSW – Vic	1.000
	Vic	1.95	0.82	2			NSW – Tas	0.002
	Tas	2.34	0.92	2			Vic – Tas	0.045
	Club Member	2.08	1.01	2	W = 5643.5	0.573		
	Not Member	2.08	0.82	2				
	Release Most	2.09	0.96	2	H = 0.051	0.975		
	Equal	2.04	0.79	2				
	Keep Most	2.05	0.74	2				
Commercial fishing bycatch and discards	NSW	4.19	0.91	4	H = 3.744	0.154		
	Vic	3.90	0.99	4				
	Tas	3.91	1.04	4				
	Club Member	4.15	0.91	4	W = 4363	0.044		
	Not Member	3.84	1.07	4				
	Release Most	4.07	0.98	4	H = 4.990	0.083		
	Equal	3.92	0.86	4				
	Keep Most	3.63	1.19	4				
Loss of prey species	NSW	3.05	1.23	3	H = 2.730	0.255		
	Vic	3.00	1.27	3				
	Tas	3.32	1.29	3				
	Club Member	3.07	1.36	3	W = 4986	0.559		
	Not Member	3.20	1.19	3				
	Release Most	3.23	1.27	3	H = 2.798	0.247		
	Equal	3.04	1.20	3				
	Keep Most	2.85	1.28	3				

Table 4.7 continued…

Proposed Regulation	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
Global warming	NSW	1.98	1.05	2	H = 1.265	0.531		
	Vic	2.19	1.23	2				
	Tas	2.28	1.31	2				
	Club Member	1.91	1.07	2	W = 4869.5	0.016		
	Not Member	2.36	1.28	2				
	Release Most	2.20	1.25	2	H = 0.298	0.861		
	Equal	2.18	1.14	2				
	Keep Most	2.03	1.12	2				
Pollution	NSW	2.49	1.24	2	H = 1.438	0.487		
	Vic	2.70	1.12	3				
	Tas	2.76	1.29	3				
	Club Member	2.51	1.14	2	W = 4458	0.191		
	Not Member	2.77	1.27	3				
	Release Most	2.66	1.21	3	H = 3.592	0.166		
	Equal	3.04	1.33	3				
	Keep Most	2.39	1.17	2				
Lack of appropriate management	NSW	2.92	1.15	3	H = 1.152	0.562		
	Vic	2.77	1.11	3				
	Tas	3.01	1.17	3				
	Club Member	3.00	1.16	3	W = 4357.5	0.267		
	Not Member	2.83	1.13	3				
	Release Most	2.98	1.15	3	H = 2.765	0.251		
	Equal	2.78	0.90	3				
	Keep Most	2.67	1.27	2				

Table 4.7 continued…

Proposed Regulation	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Lack of science in management	NSW	2.95	1.16	3	H = 0.1161	0.944		
	Vic	3.00	1.27	3				
	Tas	2.95	1.11	3				
	Club Member	3.11	1.18	3	W = 3713.5	0.120		
	Not Member	2.84	1.14	3				
	Release Most	3.00	1.14	3	H = 0.957	0.620		
	Equal	2.96	1.15	3				
	Keep Most	2.78	1.26	2.5				

Perceptions on fisheries management in Australia

The strongest agreement received from respondents was in relation to the statement “I believe that fisheries management is needed to keep fisheries sustainable”, this was followed by agreement for regulations not being enforced enough and support for precautionary management in the face of limited knowledge on fish stocks. Tas anglers reported significantly less agreement with the statement “I think that fisheries management is often used as a tool of 'the green movement” relative to NSW anglers. NSW anglers disagreed with the statement “Current fisheries regulations are generally based on reliable science”, which was a significant difference to respondents from both Vic and Tas who generally agreed with this statement. Club members expressed significantly more disagreement relative to non-members with the statement “The reasons for regulations are generally communicated in an easy to understand manner”. There was also a significant difference in agreement with the statement “Regulations are not enforced enough”, with release oriented anglers agreeing with this statement more than retain oriented anglers (*Table 4.8*).

Table 4.8: Rated agreement with statements relating to game fishers views on existing fisheries management and fishing regulations for sharks, tunas and marlins in their current state of residence. Mean and median range is based on response codes for strongly agree (1), agree (2), neutral (3), disagree (4) and strongly disagree (5).

Statement	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I believe that fisheries management is needed to keep fisheries sustainable	NSW	1.67	0.71	2	H = 0.748	0.688		
	Vic	1.59	0.64	2				
	Tas	1.56	0.64	1				
	Club Member	1.58	0.65	1.5	W = 6029.5	0.572		
	Not Member	1.63	0.67	2				
	Release Most	1.56	0.66	1	H = 3.151	0.207		
	Equal	1.64	0.57	2				
	Keep Most	1.76	0.97	2				
I think fisheries regulations often 'go too far'	NSW	2.67	1.11	3	H = 5.901	0.052	NSW – Vic	0.168
	Vic	3.08	1.16	3			NSW – Tas	0.068
	Tas	3.09	1.07	3			Vic - Tas	1.000
	Club Member	2.91	1.11	3	W = 6042	0.581		
	Not Member	2.98	1.13	3				
	Release Most	2.99	1.16	3	H = 1.107	0.575		
	Equal	2.76	0.83	3				
	Keep Most	2.92	1.12	3				
I think regulations in general are not strict enough	NSW	2.91	0.96	3	H = 0.142	0.931		
	Vic	2.84	0.97	3				
	Tas	2.89	0.95	3				
	Club Member	2.84	1.03	3	W = 6014.5	0.616		
	Not Member	2.91	0.89	3				
	Release Most	2.83	0.97	3	H = 1.685	0.431		
	Equal	2.84	0.94	3				
	Keep Most	3.11	0.89	3				

Table 4.8 continued…

Statement	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I think that fisheries management is often used as a tool of 'the green movement'	NSW	2.17	1.03	2			NSW – Vic	0.773
	Vic	2.41	1.22	2	H = 12.273	0.002	NSW – Tas	0.002
	Tas	2.84	1.18	3			Vic – Tas	0.099
	Club Member	2.36	1.19	2	W = 6576.5	0.081		
	Not Member	2.62	1.16	3				
	Release Most	2.54	1.22	3				
	Equal	2.20	1.04	2	H = 2.161	0.340		
	Keep Most	2.61	1.05	2				
Current fisheries regulations are generally based on reliable science	NSW	3.21	1.00	3			NSW – Vic	0.007
	Vic	2.66	0.87	3	H = 16.089	0.0003	NSW – Tas	0.0004
	Tas	2.63	0.93	2			Vic – Tas	1.000
	Club Member	2.90	1.00	3	W = 5225	0.191		
	Not Member	2.75	0.95	3				
	Release Most	2.91	0.94	3				
	Equal	2.52	1.19	2	H = 5.581	0.061		
	Keep Most	2.63	0.88	3				
The reasons for regulations are generally communicated in an easy to understand manner	NSW	3.06	1.01	3				
	Vic	2.89	1.16	3	H = 4.281	0.118		
	Tas	2.72	1.00	2				
	Club Member	3.05	1.12	3	W = 4837.5	0.030		
	Not Member	2.75	0.99	3				
	Release Most	2.90	1.01	3				
	Equal	2.68	1.22	2	H = 1.107	0.575		
	Keep Most	2.95	1.11	3				

Table 4.8 continued…

Statement	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Regulations are not enforced enough	NSW	2.12	1.09	2				
	Vic	2.23	0.99	2	H = 0.740	0.691		
	Tas	2.21	0.96	2				
	Club Member	2.07	0.98	2	W = 6504.5	0.108		
	Not Member	2.29	1.03	2				
	Release Most	2.05	0.98	2			Release – Equal	0.142
	Equal	2.40	0.76	2	H = 12.052	0.002	Release – Keep	0.005
	Keep Most	2.66	1.12	3			Equal – Keep	1.000
In the face of limited scientific knowledge about fish stocks, management should be precautionary. (for example: If a species is being fished with little scientific knowledge of the stock size, or the stocks ability to recover from fishing; management should regulate fishing to prevent irreversible damage until more is known)	NSW	2.41	1.07	2				
	Vic	2.52	0.98	2	H = 4.211	0.122		
	Tas	2.19	0.89	2				
	Club Member	2.33	0.98	2	W = 5866.5	0.872		
	Not Member	2.39	0.98	2				
	Release Most	2.30	0.96	2				
	Equal	2.52	1.08	2	H = 2.695	0.260		
	Keep Most	2.53	0.98	3				

Regarding the reasons that anglers may not follow fisheries regulations, respondents expressed the highest agreement with the statements "commercial fishing takes too many sharks", "Regulations that force me to release all mako sharks I catch will still result in some of these sharks dying; which would be a waste of the resource", "I do not think enough is currently known about Australian mako populations to form effective regulations" and "Recreational fishing has little effect on the mako shark population". Relative to the other two states, anglers from NSW rated significantly higher agreement to all reasons listed for not following management regulations, except regulations being too confusing (*Table 4.9*). Similarly, compared to non-members, club members rated significantly greater agreement to regulations not being followed because they believed not enough was known about shark populations, shark populations were not in trouble and they did not have much trust in management; although the latter two of these statements were still rated as slight disagreement. No significant differences of opinion were observed between fishing preference groups.

The hypothetical management regulation that garnered the most support from respondents was a seasonal possession limit of mako shark per person per year, this was followed in support by size restrictions and mandatory use of circle hooks (*Table 4.10*). The least popular (greatest opposition) to a hypothetical management regulation was found in relation to the species being designated as mandatory catch-and-release. This was followed in unpopularity by closed seasons and a tagging system to limit harvest. Those that release most of their catch were significantly more likely to support mandatory catch-and-release than those who retain sharks more frequently, however both groups still expressed overall disagreement with this proposed regulation. Respondents who routinely release sharks were also significantly more likely to support maximum size limits, season possession limits, closed seasons and mandatory use of circle hooks relative to those respondents who show either equal preference or higher preference for retaining sharks. Club members showed significantly less agreement with maximum size limits and closed seasons relative to non-members. Tasmanian respondents reported significantly more agreement with season possession limits, closed seasons and permit to keep tags relative to respondents from NSW or Vic.

Table 4.9: Rated agreement with suggested reasons that anglers may not adhere to fisheries regulations, mean and median range is based on response codes for strongly agree (1), agree (2), neutral (3), disagree (4) and strongly disagree (5).

Reason regulations may not be followed	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Regulations can be too confusing	NSW	3.16	1.18	3				
	Vic	3.10	1.26	3	H = 0.368	0.832		
	Tas	3.05	1.15	3				
	Club Member	3.01	1.16	3	W = 5836	0.395		
	Not Member	3.15	1.20	3				
	Release Most	3.14	1.21	3				
	Equal	3.08	1.14	3	H = 1.290	0.525		
	Keep Most	2.92	1.11	3				
Regulations are not needed because populations of mako sharks are not in trouble	NSW	2.97	1.10	3			NSW – Vic	0.557
	Vic	3.25	0.92	3	H = 7.756	0.021	NSW – Tas	0.016
	Tas	3.47	1.02	4			Vic - Tas	0.554
	Club Member	3.10	0.98	3	W = 6003	0.046		
	Not Member	3.36	1.06	3				
	Release Most	3.27	1.05	3				
	Equal	3.33	0.92	3.5	H = 1.355	0.508		
	Keep Most	3.11	1.06	3				
Commercial fishing takes too many sharks	NSW	1.71	0.81	2			NSW – Vic	0.308
	Vic	2.00	0.97	2	H = 12.573	0.002	NSW – Tas	0.001
	Tas	2.27	0.99	2			Vic – Tas	0.240
	Club Member	2.03	1.01	2	W = 4993.5	0.983		
	Not Member	2.01	0.92	2				
	Release Most	1.96	0.96	2				
	Equal	2.04	0.81	2	H = 2.167	0.338		
	Keep Most	2.22	1.05	2				

Table 4.9 continued…

Reason regulations may not be followed	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
Recreational fishing has little effect on the mako shark population	NSW	2.29	1.11	2			NSW – Vic	0.110
	Vic	2.67	1.03	3	H = 11.350	0.003	NSW – Tas	0.002
	Tas	2.88	1.06	3			Vic – Tas	0.890
	Club Member	2.64	1.14	2	W = 5335.5	0.809		
	Not Member	2.65	1.05	3				
	Release Most	2.70	1.13	3				
	Equal	2.57	0.99	2	H = 0.885	0.642		
	Keep Most	2.47	0.97	2				
Current levels of catch-and-release fishing conserve stocks without need for additional regulations	NSW	2.48	0.97	2			NSW – Vic	0.831
	Vic	2.71	0.92	3	H = 11.542	0.003	NSW – Tas	0.003
	Tas	3.05	0.96	3			Vic – Tas	0.118
	Club Member	2.71	0.97	3	W = 5001	0.547		
	Not Member	2.80	0.99	3				
	Release Most	2.75	0.99	3				
	Equal	2.61	0.99	3	H = 1.286	0.526		
	Keep Most	2.91	0.97	3				
Regulations that force me to release all mako sharks I catch will still result in some of these sharks dying; which would be a waste of the resource	NSW	2.45	0.99	2			NSW – Vic	0.009
	Vic	1.93	0.86	2	H = 8.931	0.011	NSW – Tas	0.186
	Tas	2.15	0.97	2			Vic – Tas	0.526
	Club Member	2.14	0.93	2	W = 5665.5	0.841		
	Not Member	2.19	0.99	2				
	Release Most	2.27	1.01	2				
	Equal	1.88	0.78	2	H = 4.839	0.089		
	Keep Most	1.94	0.80	2				

Table 4.9 continued…

Reason regulations may not be followed	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
I do not have much trust in management or scientific advice	NSW	3.20	1.14	3			NSW – Vic	0.784
	Vic	3.41	1.26	4	H = 7.387	0.025	NSW – Tas	0.021
	Tas	3.72	1.01	4			Vic – Tas	0.465
	Club Member	3.24	1.08	3	W = 6449	0.010		
	Not Member	3.63	1.16	4				
	Release Most	3.47	1.16	4				
	Equal	3.70	1.06	4	H = 1.764	0.414		
	Keep Most	3.29	1.13	3				
I do not think enough is currently known about Australian mako populations to form effective regulations	NSW	2.20	0.86	2			NSW – Vic	1.000
	Vic	2.35	1.06	2	H = 9.515	0.009	NSW – Tas	0.012
	Tas	2.74	1.07	3			Vic – Tas	0.082
	Club Member	2.28	0.95	2	W = 5681.5	0.028		
	Not Member	2.61	1.07	3				
	Release Most	2.44	0.96	2				
	Equal	2.54	1.22	2	H = 0.058	0.971		
	Keep Most	2.51	1.17	3				

Table 4.10: Respondents opinions on hypothetical management regulations; mean and median range is based on response codes for strongly agree (1), agree (2), neutral (3), disagree (4) and strongly disagree (5).

Proposed Regulation	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
Mako sharks to be strictly catch-and-release only	NSW	3.67	1.21	4				
	Vic	3.97	0.95	4	H = 1.757	0.415		
	Tas	3.70	1.22	4				
	Club Member	3.89	1.12	4	W = 5112.5	0.116		
	Not Member	3.67	1.15	4				
	Release Most	3.58	1.18	4			Release – Equal	0.002
	Equal	4.40	0.65	4	H = 15.883	0.0004	Release – Keep	0.024
	Keep Most	4.11	1.01	4			Equal – Keep	1.000
Minimum size limits on mako sharks	NSW	2.64	1.35	2				
	Vic	2.33	1.14	2	H = 2.410	0.299		
	Tas	2.31	1.28	2				
	Club Member	2.38	1.22	2	W = 5875.5	0.858		
	Not Member	2.44	1.29	2				
	Release Most	2.32	1.24	2				
	Equal	2.52	1.29	2	H = 3.606	0.165		
	Keep Most	2.71	1.29	2.5				
Maximum size limits on mako sharks	NSW	2.68	1.33	3				
	Vic	2.49	1.35	2	H = 2.559	0.278		
	Tas	2.36	1.38	2				
	Club Member	2.72	1.32	3	W = 4769.5	0.021		
	Not Member	2.32	1.35	2				
	Release Most	2.30	1.31	2			Release – Equal	0.066
	Equal	3.00	1.50	3	H = 10.023	0.007	Release – Keep	0.034
	Keep Most	2.89	1.27	3			Equal – Keep	1.000

Table 4.10 continued…

Reason regulations may not be followed	**State / Club Member / Fishing Preference**	**Mean**	**SD**	**Median**	**Kruskal- Wallis / Mann-Whitney**	**P**	**Pairwise Comparisons**	**P**
A season possession limit of mako shark per person per year	NSW	2.65	1.32	2			NSW – Vic	1.000
	Vic	2.74	1.30	2	H = 20.986	<0.0001	NSW – Tas	0.0008
	Tas	1.91	1.06	2			Vic – Tas	0.0002
	Club Member	2.51	1.31	2	W = 5168	0.169		
	Not Member	2.27	1.23	2				
	Release Most	2.25	1.26	2			Release – Equal	0.066
	Equal	2.84	1.28	2	H = 6.816	0.033	Release – Keep	0.321
	Keep Most	2.55	1.20	2			Equal – Keep	1.000
Closed seasons for fishing mako sharks	NSW	3.36	1.21	3.5			NSW – Vic	1.000
	Vic	3.43	1.26	4	H = 7.070	0.022	NSW – Tas	0.090
	Tas	2.91	1.26	3			Vic – Tas	0.043
	Club Member	3.49	1.18	4	W = 4515	0.004		
	Not Member	2.98	1.27	3				
	Release Most	3.10	1.25	3			Release – Equal	0.009
	Equal	3.88	0.97	4	H = 9.005	0.011	Release – Keep	1.000
	Keep Most	3.13	1.32	3			Equal – Keep	0.055
Mandatory use of circle hooks to reduce hooking damage in sharks	NSW	2.44	1.23	2.0				
	Vic	2.67	1.14	3	H = 1.572	0.456		
	Tas	2.49	1.24	2				
	Club Member	2.67	1.19	3	W = 5090.5	0.115		
	Not Member	2.42	1.22	2				
	Release Most	2.30	1.14	2			Release – Equal	0.013
	Equal	3.04	1.24	3	H = 19.102	<0.0001	Release – Keep	0.0006
	Keep Most	3.13	1.19	3			Equal – Keep	1.000

Table 4.10 continued…

Reason regulations may not be followed	State / Club Member / Fishing Preference	Mean	SD	Median	Kruskal- Wallis / Mann-Whitney	P	Pairwise Comparisons	P
A limited number of 'permit to keep' tags, sold by government each year to ensure that recreational catches are capped	NSW	3.24	1.33	3	H = 6.822	0.033	NSW – Vic	1.000
	Vic	3.44	1.18	3			NSW – Tas	0.272
	Tas	2.85	1.47	3			Vic – Tas	0.036
	Club Member	3.23	1.35	3	W = 5438	0.427		
	Not Member	3.08	1.37	3				
	Release Most	3.02	1.39	3	H = 4.253	0.119		
	Equal	3.40	1.19	4				
	Keep Most	3.47	1.29	3.5				

Discussion

This study reports valuable information regarding the gear choices and fishing preferences of Australian shortfin mako shark anglers and relates these to their perceptions of sharks and fisheries management in an effort to better understand the practices and choices of anglers who participate in this fishery. Selection of gear was shown to be determined largely by the fishing preference of the angler, with those practising catch-and-release more frequently using circle hooks more often. As in Chapter 3, geography also played a large part in determining the perceptions and behaviours of fishers with the largest differences being noted between NSW and Tas. Generally, Vic respondents were found to express an intermediate opinion relative to these two states, or one that was more closely aligned to either Tas or NSW depending on the issue. NSW respondents were also found to be almost contradictory in the sense that this group used circle hooks more commonly than respondents from the other two states and had the highest release rates (Chapter 3), yet also indicated the least support and trust for fisheries management. The potential for recreational fishing to impact shark stocks was also the least acknowledged by this group, which may help explain their lack of support for any future management, if it were found necessary. Based on this lack of acknowledgment or potential lack of responsibility, it may be that one of the greatest impediments to promoting responsible fishing for mako sharks could be mitigated through improved communication between stakeholders and angler education initiatives.

Beliefs about shark survival and relation to gear use

Overall respondents indicated that they believed sustaining body lacerations from the trace, being bought on deck and being played on the line for a long duration were the least likely of the presented scenarios to result in post release mortality; under these situations sharks were believed to have a higher than 50/50 chance at survival. Interestingly, long fight times were rated significantly less detrimental for a shark’s welfare by club members when compared with non-members. This may be related to differing practices between club members and non-members, where the former can be expected to play sharks on the line for longer periods, particularly when tournament rules specify lighter gauge line must be used (TGFA, 2016). I.E. fishers are effectively endorsing their own behaviours as being acceptable.

Current research indicates that long fight times and time out of water can reduce the chance of a fish surviving (Cooke and Suski, 2005; Heberer *et al.*, 2010), however species with high aerobic scopes such as some scombrids and lamnids have been found to be capable of dealing with extensive capture times without succumbing to mortality (Chapter 2; Tracey *et al.*, 2016). As such, it is less likely that long angling durations will impact the survival of these species given that respiration is not impeded, for example if the shark is dragged backwards during capture or removed from the water for extended periods (Chapter 2; Heberer *et al.*, 2010; Sepulveda *et al.*, 2015). Interestingly, Tas anglers rated the chances of survival for sharks that were wrapped in the line and dragged backwards during capture significantly higher than did both Vic and NSW anglers, who believed the chance of these sharks surviving was unlikely. It is unclear why Tas anglers hold such a differing opinion with regards to this scenario. Research on recreationally fished thresher sharks shows that pulling obligate ram ventilators backwards for the duration of the fight substantially reduces the likelihood of post-release survival (Skomal, 2007; Heberer *et al.*, 2010; Sepulveda *et al.*, 2015). Bringing sharks aboard is also discouraged from a catch welfare perspective, as respiration is inhibited and the potential for physiological recovery is greatly reduced (Cooke and Suski, 2005).

Furthermore, anglers believed that sharks that were bleeding heavily, hooked in the gills and those that appeared non-responsive boat-side were unlikely to survive. Heavy bleeding and damaged gills caused by hooking has previously been found to be associated with post-release mortality in a number of fishes, including shortfin mako sharks (Chapter 2; Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Epperly *et al.*, 2012). For shortfin mako, evidence exists to show that much of this hooking damage may be prevented by the use of circle hooks (Chapter 2; Epperly *et al.*, 2012) which as the results of this study show, is a belief generally held by anglers. Despite respondents rating hook damaged sharks unlikely to survive and agreeing that circle hooks were an effective way of reducing hooking damage, circle hook use in this sample of anglers is not as high as would be expected even when catch-and-release fishing. These findings are in agreement with recent research that has found a disconnect with the desire to promote released shark welfare and a lack of adherence to best-practice recommendations (McClellan Press *et al.*, 2016).

When targeting shortfin mako for catch-and-release, circle hooks were the most commonly used hook type, although overall, most anglers reported using this gear less frequently than "mostly". Circle hook use during catch-and-release fishing was significantly lower amongst Tas and Vic respondents compared with their NSW counterparts, a response that appears to be related to variability in rates of participation in catch-and-release fishing between states (Chapter 3). Contrastingly, when sharks were targeted for retention, circle and J hooks were utilised almost equally with anglers rating the average frequency of circle hook use less often than "sometimes". At the very least this indicates that a proportion of game fishers are actively selecting specific gears to suit different fishing outcomes; to my knowledge this aspect of fisher behaviour has not been reported before and demonstrates that some anglers voluntarily make decisions that improve the welfare of their released catch. Additionally, when catch-and-release fishing, release oriented anglers reported utilising circle hooks more frequently than respondents who retained most of their catch; the latter group being significantly more likely to utilise J hooks. Anglers from NSW have been shown to release a higher portion of their shortfin mako sharks than both Tas and Vic anglers (Chapter 3) and the tendency for NSW anglers to use circle hooks more frequently than both Vic and Tas anglers likely correlates with these fishing preferences. These findings appear to confirm that to some degree, hook selectivity corresponds with fishing motive as well as behavioural norms (Heywood, 2011), for example; fishers that more routinely practise catch-and-release will be more likely to use circle hooks.

The beliefs or perceptions of anglers regarding the effectiveness and usability of gears can prove to be a great barrier to their adoption into common use (Cooke *et al.*, 2012). The model tested in this study examined the agreement that anglers showed towards proposed benefits of using circle hooks (with regards to catch welfare, effectivity and ease of use), contrasted against the potential for circle hooks to reduce catch rates and a general dislike for their use. Results indicated that respondents were generally aware of the benefits circle hooks can provide, in particular those to catch welfare. Cooke *et al.* (2012) found that the majority of circle hook users that responded to their online study agreed that circle hooks reduce instances of deep hooking relative to conventional hook designs (87.5%) and represent an important fish conservation tool (76.9%). Cooke *et al.* (2012) also identified that the most common challenges facing circle hook use were associated with existing angler beliefs that the gear is ineffective at capture and that circle hooks are difficult to use. Data in the current study contrasts the findings of Cooke *et al.* (2012), revealing general disagreement from shortfin mako anglers regarding the potential of circle hooks to hinder their catch rates. Most anglers also agreed that they knew how to use circle hooks correctly when fishing for sharks and disagreed that using circle hooks made fishing for mako sharks too hard compared to using J hooks. From these results it could be assumed that most anglers would be willing to adopt circle hooks into common use, or at least that behavioural norms where circle hooks are used may be established through better promotion. It is interesting that given anglers' positive perceptions of circle hooks that they are already not in wider use given the conservation advantages these hooks can pose to intentionally and accidentally released sharks. More consistent promotion through outdoor media and tackle shops may aid in more widespread adoption of this gear (Cooke *et al.*, 2012).

Perceptions on sharks and threats to shark populations

If future management is required to sustain shortfin mako populations, the success of any legislation will be influenced by the support of the general public. This could prove difficult if individuals have existing negative perceptions about sharks, particularly those perceptions concerning fear of sharks as commonly sensationalised through the media (Philpott, 2002; O'Bryhim, 2009; Muter *et al.*, 2013; Neff, 2015). Negative perceptions of sharks may reduce public support for their protection, or even become the basis of opposition to it (Philpott, 2002; O'Bryhim, 2009). However, recently, the cull of sharks in Western Australia has revealed that substantial community support for shark conservation exists (Gibbs and Warren, 2014). On the other hand, even if no negative perceptions about sharks exist, the simple belief that there may be no need to protect them, or that enough is not known about current impacts may create a barrier to any possible regulations (Bruce, 2014). Overall, most respondents in the current study believed that mako sharks were not a danger to people outside of fishing and most agreed that they would not fish for mako sharks if they thought the activity was unsustainable. Therefore it is reasonable to assume that the fishing behaviour of respondents is not influenced by pre-existing biases against sharks. In fact many respondents, particularly those from NSW, believe that they regularly take steps to minimise their impacts on shark populations, which likely manifests as a higher percentage of sharks that are released after they are caught (Chapter 3). This also relates to the relatively higher agreement with the statement "I regularly take steps to minimise my impact on shark stocks" expressed by release oriented anglers in this study. Although many anglers indicated that they would not fish for sharks unsustainably, many also expressed awareness that stocks are not able to recover quickly from overfishing, highlighting an awareness of the vulnerability of shark populations to fishing pressures.

Existing research indicates that recreational fishing can and does contribute to the exploitation of fisheries resources worldwide (Mc Phee *et al.*, 2002; Post *et al.*, 2002; Coleman *et al.*, 2004; Cooke and Cowx, 2004; Cooke and Cowx, 2006; Lewin *et al.*, 2006). However, this information is not acknowledged or accepted by many of the respondents in the current study, at least in the context of their personal fishing behaviours in relation to shortfin mako stocks. NSW anglers in particular even disagreed that recreational fishing had the ability to impact mako shark stocks altogether which may relate to the higher participation in catch-and-release fishing by anglers from this state. My results show that respondents believe commercial fishing to be a greater threat to shortfin mako populations above the loss of prey species, lack of science in management, lack of appropriate management, pollution, global warming and finally rating recreational fishing the least significant threat, despite the two sectors imposing many of the same impacts on fish stocks (Cooke and Cowx, 2006). A lack of accountability for ecosystem effects caused by personal fishing behaviours has also been noted amongst saltwater anglers in the United States with commercial fishing being rated the highest threat by a substantial margin, and subsequently followed by concerns over management effectiveness and finally global warming; recreational fishing was not identified as a threat to fisheries resources in the U.S. study at all (Gray and Jordan, 2010). It is somewhat striking that despite how similar the broader impacts of commercial and recreational fishing are (Cooke and Cowx, 2006), that the perceived threat that these two sectors pose to shark stocks has been rated so differently by anglers.

Perceptions on management and support for regulations

How anglers viewed the effect of commercial fisheries on mako shark stocks was also rated by respondents in this study to be the most likely reason that regulations on recreational fishing may not be adhered to with recreational fishers even potentially ignoring management regulations based on the belief that their own impacts are insignificant in comparison to those of the commercial sector. Respondents also expressed that they believed not enough was known about shortfin mako stocks to form effective regulations, and that regulations specifying mandatory catch-and-release may not be adhered to because the occurrence of post-release mortality would result in wastage of the resource. NSW anglers expressed significantly more agreement for all potential reasons that regulations may not be followed, with the exception of the regulations being too confusing. This flags a potential support issue between fisheries management and recreational fishers in NSW. It could be speculated that NSW anglers may have expressed a higher distrust in management following contention over the establishment of marine protected areas (MPAs) in NSW (Claughton, 2014; Voyer *et al.*, 2014; Martin *et al.*, 2016). However, the same could be said about Tasmanian angler's contention over the Commonwealth government's initial backing of the 'super trawler' *FV Margiris* to fish waters adjacent to south-eastern Australia (Tracey *et al.*, 2013a; Wainwright, 2015). Furthermore, recent research has shown that a much higher proportion of recreational anglers now show positive attitudes to the MPAs in NSW (Martin *et al.*, 2016). As such, reasons for the differing management support between states are unclear.

Frequent positive interactions between anglers, scientists and fisheries managers are essential to the trust and cooperation between these groups and compliance with fisheries regulations (Danylchuk and Cooke, 2011; Cardona and Morales-Nin, 2013). Consequently, there is a need to understand the current perceptions and attitudes towards management before any attempts to move forward with the cooperation of anglers can be made (Cardona and Morales-Nin, 2013). Overall, respondents expressed their agreement for the need of fisheries management to keep fisheries sustainable and also indicated that more enforcement of fisheries management regulations was needed. Respondents from all states indicated general agreement with fisheries management being used as a tool of the "green movement" which indicates that to some degree, political beliefs are reflected in fisher behaviour. NSW anglers expressed the most agreement with this statement and also indicated that they do not believe current fisheries regulations are based on reliable science; this group expressed the least trust in fisheries management compared to anglers from Vic and Tas. NSW anglers were also most likely to believe that fisheries regulations on sharks, tunas, and marlin in their state "go too far", despite regulations between all three states being very similar (DPIPWE, 2016; NSW Government, 2016; Victorian State Government, 2016). Although not significantly different to the other two states, NSW anglers expressed the least agreement with the statement "The reasons for regulations are generally communicated in an easy to understand manner" which may help explain why this group were generally less supportive of fisheries management authorities relative to anglers from the other two states. Previous studies have highlighted anglers' limited understanding of, and support for, fisheries regulations stemming from poor communication between management agencies and the public, with most information being spread by word of mouth between anglers (Cardona-Pons *et al.*, 2010; Cardona and Morales-Nin, 2013).

Effective communication may be best achieved by actively integrating recreational fishers in the decision making process and failure to do so may contribute to opposition to conservation efforts and incite conflict between managers and resource users (Danylchuk and Cooke, 2011). As such, the final component of the current study has examined the support for a range of hypothetical management measures that may apply to recreational shortfin mako fishing. Regulations that garnered the most overall support from anglers were seasonal possession limits of mako shark per person per year, minimum and maximum size limits and the mandatory use of circle hooks. The most opposition from anglers was to mandatory catch-and-release and those regulations that limited their current fishing opportunities, such as closed seasons and limited numbers of purchasable licences sold by the government each year to cap recreational catches. Although not all of these hypothetical regulations would be effective, it is important to know which types of regulation will encounter the most resistance from anglers and which are most likely to be accepted into common use.

Summary

Overall, these data indicate that with a few exceptions, game fishers have generally realistic and accurate perceptions about how their fishing behaviours and gear choices may affect the survival of released shortfin mako sharks. It is interesting to note that a large proportion of anglers still utilise J hooks for both keeping and releasing sharks despite their positive perceptions of circle hooks, particularly perceptions with regard to how this gear can reduce the incidence of deep hooking and hence post-release mortality. It is worth mentioning that while it may be commonly thought that the overall welfare of sharks targeted for retention is of little importance given their intended fate, this mentality does not account for sharks that are hooked, yet ultimately not captured due to line breakages or hooks tearing free. As a consequence, the survival of sharks that are hooked and not landed is questionable (Afonso *et al.*, 2012) and as such, there would be benefits for the sharks and fishery if circle hooks were used regardless of whether the intention is to retain or release them.

It is also clear that better communication between recreational fishers, management authorities and fisheries scientists is required; if future management of shark stocks is necessary, the success of this will be influenced by public attitudes. The actual impact of recreational fishing on shortfin mako populations remains unknown; however, angler support for precautionary management suggests that a better understanding of the potential impacts of recreational fishing on shortfin mako stocks may assist in promoting greater accountability and responsible fishing practices amongst these resource users. As the total impact on shortfin mako stocks by recreational fishers is unknown, responsible fishing techniques such as using circle hooks and minimising air exposure should also be promoted to maximise the survival of dropped or released sharks.

Chapter 5
General Discussion

This study provides a deeper understanding of the impacts of recreational shark fishing in Australia with implications that are relevant to other recreational fisheries worldwide. This thesis not only examined the effects of recreational angling on mako sharks from a physiological perspective, but integrated human dimensions information with this in order to provide a more complete picture of the fishery. Presented are estimates of shortfin mako shark survival when subjected to angling, detail of the physiological response to angling and factors that may improve or diminish the survivorship in this species under recreational fishing conditions. This information is examined alongside the motivations and fishing behaviours of the anglers that target this species.

Given both stock status and total harvest are unknown, the ecological sustainability of the recreational fishery for this species is uncertain. However, various aspects of the shark's biology are known, and these indicate that the species is slow growing, late to mature and produces relatively few offspring – hence, populations are susceptible to overfishing with any stock recovery expected to be slow. These management challenges are common amongst many elasmobranch species and as such, it is appropriate to adopt a precautionary approach until more is known about shark populations (Musick *et al.*, 2000). This is a sentiment that is shared by many game fishers (Chapter 4) and promoted internationally through the Code of Conduct for Responsible Fisheries along with other considerations that examine sustainability from varying stakeholder perspectives (FAO, 1995; Hilborn *et al.*, 2015) . The concept of responsible fishing is promoted in an effort to integrate these perspectives and manage fisheries as dynamic socio-ecological systems (SES) (Arlinghaus *et al.*, 2016).

Defining Responsible Fishing

In response to growing concern over the long-term sustainability of global fisheries, clear signs of over-exploitation and ecosystem damage, the Food and Agriculture Organization (FAO) developed the Code of Conduct for Responsible Fisheries (FAO, 1995). The code aims to improve the socioeconomic and ecological sustainability of both commercial and recreational fisheries by recognising the nutritional, economic, social, environmental and cultural importance of fisheries alongside the interests of industry stakeholders. However, many provisions in the Code are not well aligned to recreational fishing and many of the recreational sector's impacts are not specifically addressed (FAO, 2012). Around the same time that the FAO Code of Conduct for Responsible Fisheries was being developed, the need for a national code of practice for recreational and sport fishing was identified by the Australian Government in their National Recreational Fishing Policy (Smith *et al.*, 2016). Subsequently, in 1995, the National Code of Practice for Recreational and Sport Fishing (Recfish Australia, 2010) was first developed, with the latest update addressing recreational fishers in four main areas of fishing responsibility: "treating fish humanely", "looking after our fisheries", "protecting the environment" and "respecting the rights of others". These four overriding objectives form a framework that incorporates fourteen more specific principles which are summarised in *Table 5.1*. More recently, the FAO has developed a code of practice focusing on global recreational fisheries (the FAO Technical Guidelines for Responsible Fisheries, (FAO, 2012)) which includes broader, more detailed sections on policy and institutional frameworks, recreational fisheries management actions and strategies, recreational fisheries practices and recreational fisheries research; this document is not just tailored for recreational fishers, unlike the Australian National Code, but towards stakeholders ranging from recreational fishers to researchers and managers (FAO, 2012).

Table 5.1: Summary of principles promoted for responsible recreational fishing in Recfish Australia (2010).

Treating fish humanely 1. Quickly and correctly returning unwanted or illegal catch to the water 2. Quickly and humanely killing fish that are kept for consumption 3. Using only appropriate, legal tackle, attending all fishing gear and valuing our catch
Looking after our fisheries 4. Taking no more than our immediate needs 5. Supporting and encouraging activities that preserve, restore and enhance fisheries and fish habitat 6. Understanding and observing all fishing regulations and reporting illegal fishing activities
Protecting the environment 7. Preventing pollution and protecting wildlife by removing rubbish 8. Taking care when boating and anchoring to avoid damage to wildlife and habitat 9. Using established roads and tracks 10. Reporting environmental damage 11. Avoiding unnecessary interactions with wildlife species and their habitats
Respecting the rights of others 12. Practicing courtesy towards all those who use inland and coastal waters 13. Obtaining permission from landholders and traditional owners before entering land 14. Caring for our own safety and the safety of others when fishing

It is clear from the above codes that responsible recreational fishing behaviours exceed simply reducing harvest and incorporate a wider range of behaviours that coincide largely with ecosystem stewardship concepts (Chapin Iii *et al.*, 2010).

Alignment of Current Practice with Responsible Fishing Guidelines

To evaluate whether Australian recreational fisheries align with the responsible fisheries model it is necessary to understand the behaviours and practices currently in use within this context. Treating fish humanely implies that regardless of the fate of the catch (retained or released) the angler has a responsibility to ensure that suffering, discomfort and injury to the animal is minimised. Two primary approaches exist when considering fish welfare in recreational fisheries, pragmatic and suffering-centred. The pragmatic approach considers the health and fitness of individual fishes, whereas the suffering-centred approach focuses on the moral perspective and considers the potential suffering and pain in fishes (Arlinghaus *et al.*, 2009). The former of these two is generally preferred from a fisheries development standpoint as it allows for the development of scientifically defensible recommendations to mitigate the factors and situations under which the welfare of fishes is compromised (Arlinghaus *et al.*, 2009). Whether fish are capable of experiencing pain or suffering has been thoroughly debated throughout the literature (Chandroo *et al.*, 2004; Huntingford *et al.*, 2006; Sneddon, 2006; Arlinghaus *et al.*, 2007b; Huntingford *et al.*, 2007) and without discounting the existing support for this concept, which incorporates a range of ethical considerations, this discussion will primarily focus on the pragmatic approach, as developing recommendations for improving fishing practices in the immediate future is possible (Arlinghaus *et al.*, 2009).

The capture and handling associated with fishing can lead to a range of disruptions to a sharks physiological homeostasis (Skomal, 2007). For example, elevated concentrations of plasma lactate and increased haematocrit has previously been noted in common thresher sharks (*Alopias vulpinus*) in response to rod and reel capture, with longer fight times eliciting a more pronounced stress response (Heberer *et al.*, 2010). Using lighter lines results in longer fight times and a higher likelihood of exhaustion; a concept that may be considered contrary to the principle of responsible fishing. Despite this, lighter tackle may be promoted to game fishers in the form of fishing records (GFAA, 2017b) and can also be specified as a condition of participation in some game fishing tournaments (TGFA, 2016). Physiological disruptions associated with extensive capture durations can also result in mortality, specifically when the associated physiological impacts exceed a fish's ability to return to homeostasis (Kieffer, 2000; Moyes *et al.*, 2006; Hight *et al.*, 2007; Frick *et al.*, 2010a; Frick *et al.*, 2012). The amount of physiological disruption that a shark can successfully manage without succumbing to mortality varies between species, with at-vessel mortality rates ranging from as low as 3% in tiger sharks (*Galeocerdo cuvier*) to as high as 94% in great hammerheads (*Sphyrna mokarran*) (Morgan and Burgess, 2007; Mandelman *et al.*, 2008; Mandelman and Skomal, 2009; Hyatt *et al.*, 2012; Marshall *et al.*, 2012). The shortfin mako shark has been shown to be resilient to these physiological changes, likely as a consequence of its thermal strategy (Chapter 2). However, prolonged capture events still lead to mortality in a range of other species and even robust species will be at increased risk of predation during recovery periods (Chapter 2; Kieffer, 2000; Skomal and Mandelman, 2012; Brownscombe *et al.*, 2014; Raby *et al.*, 2014)..

Although the precise methods used by anglers to catch and release sharks were not directly investigated, Chapter 4 did investigate perceptions of survivorship of sharks subjected to various fishing conditions, providing insight into practices believed appropriate for the welfare of the sharks. Results from Chapter 2 indicated that prolonged air exposure may contribute to mortality of released sharks, which is in agreement with many other empirical studies involving the post capture handing of fish (Bartholomew and Bohnsack, 2005; Gingerich *et al.*, 2007). However, mako sharks being bought on-board vessels (i.e.: air exposure) was rated by respondents as one of the least likely scenarios to impede post-release survival (Chapter 4). This unexpected result suggests that, whether or not this is a common practice amongst mako fishers, there is a need to increase community awareness of the increased risk to subsequent survival of landing sharks prior to their release. Sub-lethal effects on growth and fitness that result from the physiological disturbances associated with capture and handling are also plausible, however very little is known about how these effects manifest in different species (Wilson *et al.*, 2014).

Two key factors that can affect survival in sharks, deep hooking (including gill hooking) and heavy bleeding (Chapter 2; Campana *et al.*, 2009; Epperly *et al.*, 2012; Kneebone *et al.*, 2013) were acknowledged by most respondents in Chapter 4. Reducing the probability of capture injury and maximising the likelihood of post-release survival can be largely controlled by the fisher's choice of gear and handling procedures (Chapter 2; Cooke and Suski, 2004; Epperly *et al.*, 2012). This concept of reducing injury through gear and handling choices was realised by the majority of the angling community, as was the effectiveness of circle hooks in reducing the incidence of deep hooking (Chapter 4). Given this acknowledgement, it is expected that most fishers would seek to minimise the occurrence of hooking injuries through circle hook use, particularly when focused on catch-and-release fishing. However, circle hooks were only used occasionally during the majority of Australian shark fishing, either for catch-and-release or harvest fishing (Chapter 4; Lynch *et al.*, 2010; Heard *et al.*, 2016)). Although, it should be noted that there was evidence of variation in circle hook use in this study, both regionally and with fishing preference, with circle hook use the highest amongst anglers from NSW and those who release most of their catch (Chapter 4).

Minimising injury during capture in sharks targeted to be retained is also important and arguments for this approach can be found in both the suffering-centred and pragmatic approaches to animal welfare. From the suffering-centred approach, any unnecessary pain and suffering to the fish preceding slaughter should be minimised to comply with ethical treatment of the catch (Cooke and Sneddon, 2007; Diggles *et al.*, 2011). From the pragmatic standpoint, there is no guarantee that a hooked fish will actually be landed and any gear used on the animal in the case of a line breakage or hooks tearing free should be selected to minimise injury and subsequent negative effects (Chapter 4). As such, circle hook use represents a responsible gear choice regardless of what fate is intended for the shark. Resistance to circle hook uptake has been shown previously to be associated with angler perceptions that circle hooks may reduce catch rates, may not be effective in reducing foul hooking and can be difficult to use successfully (Cooke *et al.*, 2012). However, most respondents to the current study indicated that they knew how to use the hook type, that they believed circle hooks were effective in reducing injury to sharks and were not a hindrance to their catch rates (Chapter 4).

Interestingly, there was still evidence of a gaff being used on the rare occasion when catch-and-release fishing mako sharks (Chapter 4). This behaviour has also been observed in fishers targeting elasmobranchs in the Great Barrier Reef (Lynch *et al.*, 2010). Damage caused by a gaff would significantly reduce the chance of post-release survival, and as such these unnecessary injuries indicate that its use for catch-and-release does not represent responsible fishing practise (Recfish Australia, 2010; FAO, 2012). Despite this, 18% of fishers responding to a national government survey did not believe that using a gaff decreased the survival rate of released fish (Roy Morgan Research, 2003).

Outside of my thesis, very little research has been conducted exploring the motivations behind recreational shark anglers' gear choices and the beliefs surrounding the success of these gears. As gear plays such an important part in the outcomes of fishing activities (both in terms of animal welfare and fishing success), determining why anglers choose to use the gears they do and why they choose to avoid others represents a significant advancement in our understanding of recreational fisheries.

Responsible fishing behaviour also extends to humanly killing sharks and other fish that are to be retained (Cooke and Sneddon, 2007). This responsibility includes minimising the suffering of the animal before it is killed and as such fighting, handling, gaffing or otherwise injuring should be kept to a minimum prior to killing. This is somewhat harder to do when handling large, dangerous animals and the temptation for anglers to use less humane methods (e.g.: towing tail-roped sharks backwards in an effort to suffocate them) to subdue sharks prior to slaughter is likely higher. Additionally, game fishing competitions often require sharks to be landed un-mutilated for weigh-in (GFAA, 2017a), which precludes methods such as decapitation and pithing and may explain why the suffocation method is chosen by competition game fishers in some instances. Other methods of dispatch currently in use can range from using large knives to damage the gills facilitating rapid exsanguination, blunt force trauma to the head or a combination of all of these methods (author's personal observations).

Regardless of whether a shark is to be kept or released, anglers are recommended to monitor their gear. One current method of fishing for pelagic sharks is "floating baits" which involves creating a trail of chum in the water while suspending a baited hook (more commonly a J hook) below a balloon and waiting for a shark to take the bait. This method of fishing can increase the likelihood of deep hooking (author's personal observations) and while this has not been examined formally for sharks, fishing with slack lines or baits suspended from floats has been shown to result in deep hooking for a range of teleost species (Schill, 1996; Grixti *et al.*, 2007; Lennox *et al.*, 2015). Leaving baited hooks unmonitored also increases the chances of hooking unwanted and/or protected shark species and can also result in the entanglement and hooking of seabirds (McClymont, 2007; Abraham *et al.*, 2010; Rogers and Bailleul, 2015). Additionally, the balloons discarded in this process add pollution to the range of environmental impacts associated with this activity. Alternatively, a more responsible method currently used by some anglers involves visually monitoring the trail of chum and sighting the shark before a baited hook is offered (Rogers and Bailleul, 2015). This method almost eliminates the risk of bycatch, accidentally hooking a shark too large to handle and the pollution associated with balloon use; as such, the benefits of this method should be promoted.

Another important component of the National Code of Practice relevant to recreational shark fishing is “taking no more than our immediate needs” (Recfish Australia, 2010). This is echoed in the GFAA code of practice with the point “Take only what is needed. Exercise restraint when taking any species of fish even if no bag limits exist…” (GFAA, 2016). Catching and keeping only that which is needed relates to both the number and size of sharks retained. Generally speaking, many species of shark reach sexual maturity late in life and at large sizes, with older, larger females having a higher relative fecundity (Peres and Vooren, 1991; Mollet *et al.*, 2000; Stevens *et al.*, 2000; Semba *et al.*, 2011). Thus, it follows that the maintenance of a mature breeding population is crucial to the sustainability of the species (Walker, 1999; Birkeland and Dayton, 2005). Declines in the average sizes of shark species have occurred all over the globe indicating that a loss of larger individuals has already occurred in many regions (Campana *et al.*, 2005; Myers *et al.*, 2007; Bradshaw *et al.*, 2008; Ferretti *et al.*, 2008; McClenachan, 2009; Clarke *et al.*, 2013). The largest members of a population tend to have disproportionate positive effects on population dynamics and recovery, and their removal from populations can have equally large impacts relative to the removal of smaller individuals; as the number of large sharks is already in decline, it is important to minimise the take of these large individuals wherever possible (Shiffman *et al.*, 2014, 2015).

Defining “need” is difficult on a broad scale, as how individuals perceive their own needs will undoubtedly differ; these interpretations will depend on how fishers view the fishery and their motivations for participating in it. In first world nations, the nutritional need to fish for large offshore shark species is a rather farfetched concept, however the act of fishing and being able to provide for oneself in the process can have substantial importance to the livelihood or lifestyle of some people (Arlinghaus *et al.*, 2007a; Beardmore *et al.*, 2014; Harrison, 2014). Where the act of fishing for these animals is of more importance to a person’s sense of well-being than the harvest of the animal, catch-and-release fishing is a logical alternative. Shark release rates vary largely by species, for example: 70% of blue sharks (*Prionace glauca*) and 39% of shortfin mako were reported released by offshore game fishers in Tasmania (Tracey *et al.*, 2013b), while 100% of Port Jackson sharks (*Heterodontus portusjacksoni*), 91% of bronze whaler (*Carcharhinus brachyurus*), 90% of dusky whaler (*Carcharhinus obscurus*), 51% of gummy shark (*Mustelus antarcticus* and *M. stevensi* combined) and 29% of whiskery shark (*Furgaleus macki*) were reported released by recreational fishers in Western Australia (Ryan *et al.*, 2015). Specifically for shortfin mako, the most popular reason for retaining sharks was for consumption; however, retaining sharks as trophy captures was also common (Chapter 3). How much is “needed” by anglers is not an easy question to answer. From the perspective of representing a source of food, the eating quality of larger (more than 180 cm) sharks is widely accepted by anglers to be less than that of smaller sharks (Cahill, 2013), so it would be expected that following this logic, large sharks would be less desirable than smaller individuals to catch for consumption. However larger sharks are often desired for trophies and there is often waste associated with this practice, particularly where sharks deemed not to be eating quality are discarded. In some areas sharks killed for competitions are rarely eaten and the whole carcass is often discarded (Castro, 2010; ABC News, 2015) .

Ethical Considerations: Ethically, there exists a range of opinions on recreational fishing and there are arguments advocating both catch-and-release and harvest only fishing. Catch-and-release is commonly considered "unethical and reprehensible" across mainland Europe, whereas it is thought of more commonly throughout the United Kingdom and North America as "an ethical and conservative approach to resource utilization" (Aas *et al.*, 2002). For example, voluntarily releasing legal sized fish in Germany can result in prosecution under the Animal Protection Act (Arlinghaus *et al.*, 2007a). The European view implies that the act of fishing is in itself inherently cruel, and that participating in the activity can only be justified by the acquisition of food; i.e. subsistence fishing is morally acceptable whereas sport fishing is not (Arlinghaus *et al.*, 2007a). To illustrate this point further, sport fishing has been described as "…purposely inflicting fear, pain, and suffering on fish by forcing them to violently express their interest to stay alive" (De Leeuw, 1996). Views such as this are heavily rooted in the animal rights philosophy (Arlinghaus *et al.*, 2007a). Contrastingly, catch-and-release fishing is often promoted in many English speaking countries (e.g.: North America, Great Britain, Australia, and South Africa) as a way of maintaining fishing opportunities while minimising the impact of angling on the resource (Arlinghaus *et al.*, 2007a). Much evidence also exists to show that implementing catch-and-release encourages biological, economic and social sustainability in recreational fishing (Policansky, 2002; Arlinghaus *et al.*, 2007a). The conservation benefits of catch-and-release can however, be diminished if post-release survival rates are poor, which is why species specific assessments are required to develop best-practices and maximise the effectiveness of catch-and-release as a conservation tool for each species.

Fishing for Sharks Responsibly

What is best-practice? The uptake and utilisation of responsible fishing behaviours by the recreational fishing community is essential to the future sustainability of recreational fishing around the globe. For all recreational fishing the particulars of best-practice will vary between species, however, broader responsibilities of the fisher remain the same; using gears and techniques to minimise physiological stress, physical injury and environmental degradation, killing the catch as humanely as possible and taking only what is needed.

We now know that the shortfin mako, despite expressing defined physiological responses to capture stress, is resilient to these physiological effects, as long as respiration is not inhibited, and this may also apply to other ram ventilating, endothermic species (Chapter 2; Sepulveda *et al.*, 2015). For anglers this means that playing the shortfin mako on lighter lines for longer periods will likely not result in mortality, providing no injuries occur during capture (Chapter 2). Examples of ways to inhibit respiration and subsequent recovery include removing sharks from the water and retrieving the shark backwards (Frick *et al.*, 2010b; Heberer *et al.*, 2010; De Faria, 2012). This does not guarantee, however, that mortality will not occur due to extensive angling times, just to say that it is comparatively less likely relative to ectothermic elasmobranchs (Chapter 2). Catching species that are highly sensitive to capture stress such as hammerheads (Gallagher *et al.*, 2014) should be avoided and where incidental catches occur fight times should be minimised and the line cut as soon as possible to reduce capture stress (Gallagher *et al.*, 2015; Gallagher *et al.*, 2016). Line weight (breaking strength) can influence the duration of the capture experience, with heavier tackle allowing sharks to be retrieved in less time and thus, in a less exhausted condition (Gallagher *et al.*, 2016). In summary, taking into account the potential impacts on survival and growth and fitness that physiological disruption can cause, one should avoid removing sharks from the water and minimise angling times where possible as a precaution through the use of heavier gauge fishing line and angling techniques such as following hooked sharks to retrieve the line faster (Gallagher *et al.*, 2016).

Anglers are encouraged to use circle hooks for shark fishing due to their propensity to reduce deep hooking and subsequent mortality (Chapter 2; Cooke and Suski, 2004; Epperly *et al.*, 2012). There was general support from shark fishers for the mandatory use of circle hooks as a hypothetical management measure which was mirrored by an acknowledgement of this gear's benefits in reducing hooking damage (Chapter 4). As such, it could be expected that promoting the widespread use of circle hooks for the fishing of pelagic sharks should encounter relatively small resistance from the public and result in substantially less mortality in voluntarily and unintentionally released sharks (Chapter 2; Cooke and Suski, 2004; Epperly *et al.*, 2012). Hooks, regardless of type, should be removed where possible, which can be done with the use of bolt cutters or a specialised de-hooker (Gallagher *et al.*, 2016). Where deep hooking does occur, or the hook is otherwise not easily removed, it is recommended that anglers cut the line as close to the hook as safely possible rather than risk further internal injury attempting to remove it from the shark (Fobert *et al.*, 2009). Other serious injuries associated with capture and handling also occur when a gaff is used to control the shark. When the individual is to be released a gaff should not be used at all, whereas sharks intended for slaughter should be gaffed only if necessary to reduce unnecessary stress and potential suffering.

There is no current standard of practice recommended by governing recreational fishing authorities for recreational fishers specifically wishing to humanely kill large fish, particularly sharks. The Game Fishing Association of Australia (GFAA) Code of Practice for a Responsible Gamefish Fishery states that anglers should "Dispatch fish quickly and humanely. All fish that are taken should be killed as quickly and humanely as possible." However, the website does not provide any information on how to do this (GFAA, 2016). For general recreational fishing, the national code of practice recommends that the catch is always initially stunned by an accurate, sharp blow to the head, followed by bleeding out, pithing (spiking the brain) or decapitation (Recfish Australia, 2010). These methods are increasingly difficult to apply on larger animals and in some instances a captive bolt apparatus can be used to adequately stun large fish before pithing or exsanguination (Baumans *et al.*, 1997; Leary *et al.*, 2013). Pithing, bleeding out and decapitation are considered inhumane if not preceded by an adequate stunning blow to the head resulting in unconsciousness, similarly a stunning blow must be followed promptly by decapitation, pithing or exsanguination before consciousness is regained to be considered humane (Davie and Kopf, 2006; Leary *et al.*, 2013). Methods of dispatch such as suffocation through backward dragging or removal from the water are strongly discouraged (Davie and Kopf, 2006; Leary *et al.*, 2013). Bleeding out may also be particularly effective on active species such as scombrids and lamnids (Davie and Kopf, 2006). Together, this information would indicate that for active sharks the best method of slaughter would involve a substantial stunning blow to the head followed by rapid exsanguination; this may be performed discretely for competition fishers not wanting to land a mutilated shark by internal catastrophic damage to the gills. For less active species, pithing may be a more appropriate conclusive action following the stunning blow. Existing research indicates that minimising stress before slaughter and facilitating rapid exsanguination greatly improves the quality of the flesh for consumption (Poli *et al.*, 2005), which should provide additional incentive for anglers to use efficient and humane methods of slaughter. Additionally, as the size of the shark increases, so will the difficulty in handling and the force required to properly stun the shark, which supports the rationale of only retaining what can be safely handled, noting that smaller sharks will be easier to kill humanely.

To minimise bycatch, pollution and further minimise the chance of deep hooking it is recommended that anglers avoid the balloon fishing method and preferentially spot their catch visually before offering baited hooks. If other fishing methods are used (e.g.: live-baiting, bait drifting, bait floating) anglers should take care to weight their terminal tackle below the diving depth of seabirds and limit the amount of exposed fishing line above-surface to reduce the chance of wildlife entanglement.

Catch-and-release fishing is a logical alternative to harvesting sharks and a widely acknowledged way of reducing the impacts of fishing on shark populations (Arlinghaus *et al.*, 2007a). However, participation in catch-and-release being voluntary implies that a number of sharks will still be targeted for retention. Many anglers state that large (ca. over 60-80 kg) mako sharks tend to have an unpleasant ammonia-like taste that smaller sharks do not possess (Cahill, 2013) and as such it is reasonable to propose that when fishing for food, larger sharks would not be as desirable and should be released with the aim of a smaller shark being retained in its place. It would follow that the only other common reason for seeking to kill large sharks is for “trophies”; however, anglers generally disagreed that this was a strong motivation for retaining sharks (Chapter 3). As such, promoting the release of larger sharks as best-practice should have minimal resistance from the fishing community; in fact, maximum size limits were rated as one of the more agreeable of the hypothetical management regulations presented (Chapter 4). Additionally, avoiding the capture of larger sharks will aid in maintaining a mature breeding population (Birkeland and Dayton, 2005). As many shark species are slow to recover from fishing, it is important for recreational fishers not only to observe daily bag limits, but to limit their harvest to only that which they will realistically eat.

Regardless of whether anglers intend to catch-and-release or retain sharks, these principles taken together can help guide anglers towards responsible recreational fishing of sharks. A summary of these principles can be found in Table 5.2.

Table 5.2: Summary of principles recommended for responsible recreational shark fishing.

Minimising physiological stress	• Use heavier gears to reduce fight times. • Follow sharks to retrieve line faster and reduce fight times. • Minimise handling. • Do not remove sharks from water when releasing. • Avoid angling sensitive species such as hammerheads.
Minimising injury	• Use circle hooks to reduce deep hooking • Remove hooks where it can be done safely and without causing further injury. • When the hook cannot be removed, cut the line as close to the hook as possible. • Do not gaff sharks to be released
Humanely killing the catch	• Minimise stress before slaughter. • Always immediately stun the shark prior to slaughter. • After adequate stunning immediately destroy the brain or bleed the shark out. • Do not try to suffocate sharks by dragging them backwards.
Taking only what is needed	• Practice catch-and-release as much as possible. • Only take what you can realistically eat. • Avoid retaining sexually mature sharks.
Minimising environmental impacts and bycatch	• Always monitor fishing gear closely. • Keep tackle away from non-target wildlife. • Avoid fishing with slack line. • Avoid floating baits from balloons.

Impediments to the adoption of best-practice? Best-practice is not a ‘one size fits all’ solution for all species, as the specific gears and practices best for one species will not always be optimally suited to another. However, the above represents general best-practice (responsible) fishing methods for most pelagic sharks targeted by recreational anglers. Some barriers may exist that will inhibit the adoption of these methods by the wider community. Many principles of best-practice are relevant to general recreational fishing and shark-specific fishing activities. However, some aspects may be complicated by the size of some sharks and the dangers associated with their handling; this can be largely mitigated by selectively fishing for smaller individuals. The view that sharks are man-eaters or “mindless eating machines” has previously been identified as a significant impediment to shark conservation efforts (O’Bryhim and Parsons, 2015). This public belief can be largely attributed to the portrayal of sharks in the media, with shark attacks being the emphasis of over half of US and Australian shark-centric newspaper articles between 2000 and 2010; comparatively, shark conservation was the primary topic in only 11% of articles (Muter *et al.*, 2013). However, these views were not commonly shared by Australian game fishers (Chapter 4). The greatest impediment noted within this thesis is the lack of awareness or denial by anglers of the impacts of recreational fishing, whether these are total harvest of stocks, damage to animals (injury/suffering/reduced condition) or the environment (pollution – litter, gear, boating) (Chapter 4; Gallagher *et al.*, 2015). Logically, widespread adoption of responsible fishing behaviours will not occur if there is a failure by anglers to acknowledge and take responsibility for the impacts of their fishing. Most of the respondents to the questionnaire denied that their personal fishing behaviours were able to impact shark stocks. NSW anglers in particular, even disagreed that recreational fishing had the ability to impact shark stocks at all (Chapter 4). The simple belief that no protection is required, or that not enough is known about current impacts may create a barrier to any progress towards responsible behaviours (Bruce, 2014). This thesis shows that anglers believe commercial fishing is the greatest threat to shortfin mako populations while recreational fishing is the least significant threat, despite recreational and commercial fishing imposing many of the same impacts on fish stocks (Cooke and Cowx, 2006). Some fishers do not see the point in trying to modify their behaviours to preserve fisheries when commercial fisheries are perceived to have such a large impact (Chapter 4). This concept is not restricted to one species or locality (Gallagher *et al.*, 2015). Other views that demonstrate an opposition or distrust in management vary regionally and include a perception of fisheries management being used as a tool of 'the green movement' (political ideology), a perceived lack of reliable science backing management and a lack of effective communication between fisheries managers and the public (Chapter 4). Whether communication is unsatisfactory or whether the message is not trusted by the public highlights the same issue, relations between stakeholders need strengthening. This is particularly true in NSW where the least trust in fisheries management and the most opposition to fisheries regulations were observed (Chapter 4). Trust is critical to the acceptance of management decisions, although the path to improving trust between anglers and fisheries managers is unclear (Davenport *et al.*, 2007; Schroeder and Fulton, 2016).

Promoting Stewardship in Recreational Fisheries

The success of any legislation to sustain shark populations will be influenced by societal support and any attempts to move forward with the management of recreational shark fisheries must be done with the cooperation of recreational fishers (Schroeder and Fulton, 2016). Most anglers agreed that they would not fish for sharks if they thought the activity was unsustainable and expressed their agreement for the need of fisheries management and better enforcement of regulations (Chapter 4). It is clear that better communication between recreational fishers, management authorities and fisheries scientists is required, as there is still a perception amongst many fishers that not enough is known about shark populations to form effective management (Chapter 4). However, angler support for precautionary management suggests that successfully communicating a better understanding of the impacts of recreational fishing may assist in promoting greater accountability for this resource and responsible fishing practices amongst the users (Gallagher *et al.*, 2015).

The greatest challenge to promoting stewardship appears to be how to effectively communicate awareness of these impacts to recreational fishers in a way that engages them to take responsibility for their fishing behaviours. Although communication between managers and fishers is important, trust between these groups is inconsistent and as such there is a need to find champions of the responsible fisheries model to promote stewardship of fisheries resources. Promotion of responsible fishing through game fishing clubs would be a logical choice (Heard *et al.*, 2016), but this group represents only a small proportion of the fishing population – including the gamefish community (Henry and Lyle, 2003; Tracey *et al.*, 2013b). Additionally, although fishing club members are more specialised anglers than non-members, they do not release sharks more frequently or use more responsible gears than non-members and may require more incentive to do so during fishing competitions (Chapter 3). This is despite responsible behaviours being promoted in the GFAA code of practice for a number of years (GFAA, 2016). Another option is the recruitment of game fishing celebrities to further promote responsible fishing. Fishing celebrities are strong advocates and promoters of recreational fishing and often promote catch-and-release fishing among other elements of best-practice. While these celebrities obviously advocate some virtues of recreational fishing, a quick scan through their social media publications will also show these individuals often scrutinize the impacts of commercial fishing with one hand while simultaneously playing the recreational sector off as benign and misunderstood in the other. These views are obviously echoed by the public, as are the views on gear use and catch-and-release fishing that are often promoted by celebrities (Chapter 3 & 4). Working with fishing celebrities to educate the public about fishing, its impacts and how to minimise them undoubtedly represents a way forward.

Future Research Needs

The physiological response to capture varies wildly between shark species (Mandelman and Skomal, 2009; Hyatt *et al.*, 2012; Marshall *et al.*, 2012), however, only a handful of recreationally caught species have been assessed in terms of their sensitivity to capture stress. These physiological responses have been found to lead to mortality in a number of species, which is a particularly important consideration when promoting catch-and-release as a conservation measure (Skomal, 2007). Therefore, it is important to understand the broader groups of sharks that may be more at risk of succumbing to these physiological effects. Future investigation of the relationships between biological factors such as morphology, respiratory mode and thermal strategy with the physiological stress response and post-release mortality may prove to be a valuable tool for generalising the vulnerabilities of unassessed shark species.

One of the greatest determinants of fishing behaviour from Chapters 3 and 4 was the respondent's state of residence. This factor was strongly related to catch-and-release behaviour, gear use and support for management; however, the reasons underpinning such clear geographic variation in angler attitudes and behaviours are largely unknown. As such, future efforts should be aimed at understanding and integrating broader cultural values into fisheries research, as these values, likely play a large part in determining angler behaviours.

There exists a growing body of research calling for public education efforts around fishing and conservation, however despite some work focusing on fisheries stewardship education (Fedler, 2001), actively engaging in these education programmes and having these be effective requires increased attention. Furthermore, these educational efforts need to be tailored and applied to a range of people across varying ages, levels of experience, cultures, ethical viewpoints and fishing motivations, which presents a significant challenge to researchers and fisheries managers worldwide.

Recently, it has been increasingly acknowledged that recreational fisheries need to be viewed and managed as dynamic social-ecological systems, rather than being approached from a mono-disciplinary angle (Johnston *et al.*, 2014; Arlinghaus *et al.*, 2016; Arlinghaus *et al.*, 2017). The information presented in this thesis is one of very few current studies aiming to integrate both biological and human dimensions research to address fisheries management challenges. However, this type of research is still in relative infancy and future fisheries research should aim to incorporate multidisciplinary information, as to be effective, an understanding of both the resource and the nature in which humans interact with it is required.

References

Aalbers SA, Stutzer GM, Drawbridge MA (2004) The effects of catch-and-release angling on the growth and survival of juvenile white seabass captured on offset circle and J-type hooks. *North American Journal of Fisheries Management* 24: 793-800.

Aas Ø, Thailing CE, Ditton RB (2002) Controversy over catch-and-release recreational fishing in europe. *Recreational Fisheries: Ecological, Economic and Social Evaluation*: 95-106.

Aas Ø, Vittersø J (2000) Re-examining the consumptiveness concept: some suggestions from a confirmatory factor analysis. *Human Dimensions of Wildlife* 5: 1-18.

Abascal FJ, Quintans M, Ramos-Cartelle A, Mejuto J (2011) Movements and environmental preferences of the shortfin mako, *Isurus oxyrinchus*, in the southeastern Pacific Ocean. *Marine Biology* 158: 1175-1184.

ABC News (2015) No penalty for WA fisherman who caught four-metre tiger shark on handline. *ABC News*, Western Australia. http://www.abc.net.au/news/2015-03-27/tiger-shark-fisherman-no-penalty/6353062 Accessed: Feb, 2017.

Abraham ER, Berkenbusch K, Richard Y (2010). The capture of seabirds and marine mammals in New Zealand non-commercial fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 64*. Ministry of Fisheries, Wellington, New Zealand.

Adams DH, Borucinska JD, Maillett K, Whitburn K, Sander TE (2015) Mortality due to a retained circle hook in a longfin mako shark *Isurus paucus* (Guitart-Manday). *Journal of Fish Diseases* 38: 621-628.

AFMA (2009). Ecological risk management: report for the eastern tuna and billfish fishery. May 2009. Australian Fisheries Management Authority, Canberra, Australia, pp 23.

AFMA (2014). Australian tuna and billfish fisheries bycatch and discard workplan. In Bycatch and Discard Workplans ed, Australian Government, Canberra, Australia, pp 10.

AFMA (2016a) Gummy shark. *Australian Fisheries Management Authority*, Canberra, Australia. http://www.afma.gov.au/portfolio-item/gummy-shark/ Accessed: Dec, 2016.

AFMA (2016b) Reported landed annual catch from Commonwealth fisheries catch disposal records. *Australian Fisheries Management Authority*, Australia. http://data.gov.au/dataset/reported-landed-annual-catch-from-commonwealth-fisheries Accessed: Apr, 2016.

AFMA (2016c) Reported retained annual catch from Commonwealth fisheries logbooks. *Australian Fisheries Management Authority*, Australia. http://data.gov.au/dataset/reported-retained-annual-catch-from-commonwealth-fisheries-logbooks Accessed: Apr, 2016.

Afonso AS, Hazin FHV, Carvalho F, Pacheco JC, Hazin H, Kerstetter DW, Murie D, Burgess GH (2011) Fishing gear modifications to reduce elasmobranch mortality in pelagic and bottom longline fisheries off Northeast Brazil. *Fisheries Research* 108: 336-343.

Afonso AS, Santiago R, Hazin H, Hazin FH (2012) Shark bycatch and mortality and hook bite-offs in pelagic longlines: interactions between hook types and leader materials. *Fisheries Research* 131: 9-14.

Ambelu A, Mekonen S, Koch M, Addis T, Boets P, Everaert G, Goethals P (2014) The application of predictive modelling for determining bio-environmental factors affecting the distribution of blackflies (Diptera: Simuliidae) in the Gilgel Gibe watershed in southwest Ethiopia. *Plos One* 9: 1-10.

Anderson DK, Ditton RB, Hunt KM (2007) Measuring angler attitudes toward catch-related aspects of fishing. *Human Dimensions of Wildlife* 12: 181-191.

Arlinghaus R, Alós J, Beardmore B, Daedlow K, Dorow M, Fujitani M, Hühn D, Haider W, Hunt LM, Johnson BM, Johnston F, Klefoth T, Matsumura S, Monk C, Pagel T, Post JR, Rapp T, Riepe C, Ward H, Wolter C (2017) Understanding and managing freshwater recreational fisheries as complex adaptive social-ecological systems. *Reviews in Fisheries Science & Aquaculture* 25: 1-41.

Arlinghaus R, Cooke SJ, Coleman FC, Figueira WF, Ueland JS, Crowder LB (2005) Global impact of recreational fisheries. *Science* 307: 1561-1563.

Arlinghaus R, Cooke SJ, Lyman J, Policansky D, Schwab A, Suski C, Sutton SG, Thorstad EB (2007a) Understanding the complexity of catch-and-release in recreational fishing: an integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. *Reviews in Fisheries Science* 15: 75-167.

Arlinghaus R, Cooke SJ, Schwab A, Cowx IG (2007b) Fish welfare: a challenge to the feelings-based approach, with implications for recreational fishing. *Fish and Fisheries* 8: 57-71.

Arlinghaus R, Cooke SJ, Sutton SG, Danylchuk AJ, Potts W, Freire KdMF, Alós J, da Silva ET, Cowx IG, van Anrooy R (2016) Recommendations for the future of recreational fisheries to prepare the social-ecological system to cope with change. *Fisheries Management and Ecology* 23: 177-186.

Arlinghaus R, Schwab A, Cooke S, Cowx I (2009) Contrasting pragmatic and suffering-centred approaches to fish welfare in recreational angling. *Journal of Fish Biology* 75: 2448-2463.

Arrizabalaga H, de Bruyn P, Diaz GA, Murua H, Chavance P, de Molina AD, Gaertner D, Ariz J, Ruiz J, Kell LT (2011) Productivity and susceptibility analysis for species caught in Atlantic tuna fisheries. *Aquatic Living Resources* 24: 1-12.

Ballantyne JS (1997) Jaws: the inside story. The metabolism of elasmobranch fishes. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology* 118: 703-742.

Barreto RR, de Farias WKT, Andrade H, Santana FM, Lessa R (2016) Age, growth and spatial distribution of the life stages of the shortfin mako, *Isurus oxyrinchus* (Rafinesque, 1810) caught in the western and central Atlantic. *Plos One* 11: e0153062.

Bartholomew A, Bohnsack JA (2005) A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries* 15: 129-154.

Baum JK, Myers RA, Kehler DG, Worm B, Harley SJ, Doherty PA (2003) Collapse and conservation of shark populations in the northwest Atlantic. *Science* 299: 389-392.

Baumans V, Bernoth E-M, Bromage N, Bunyan J, Erhardt W, Flecknell P, Gregory N, Hackbarth H, Morton D, Warwick MC (1997) Recommendations for euthanasia of experimental animals: Part 2. *Laboratory Animals* 31: 1-32.

Beardmore B, Hunt LM, Haider W, Dorow M, Arlinghaus R (2014) Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers. *Canadian Journal of Fisheries and Aquatic Sciences* 72: 500-513.

Bernal D, Dickson KA, Shadwick RE, Graham JB (2001) Review: analysis of the evolutionary convergence for high performance swimming in lamnid sharks and tunas. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 129: 695-726.

Birkeland C, Dayton PK (2005) The importance in fishery management of leaving the big ones. *Trends in Ecology & Evolution* 20: 356-358.

Bland JM, Altman DG (1995) Comparing methods of measurement: why plotting difference against standard method is misleading. *Lancet* 346: 1085-1087.

Bland JM, Altman DG (1999) Measuring agreement in method comparison studies. *Statistical Methods in Medical Research* 8: 135-160.

Bornatowski H, Navia AF, Braga RR, Abilhoa V, Corrêa MFM (2014) Ecological importance of sharks and rays in a structural foodweb analysis in southern Brazil. *ICES Journal of Marine Science: Journal du Conseil* 71: 1586-1592.

Borucinska J, Kohler N, Natanson L, Skomal G (2002) Pathology associated with retained fishing hooks in blue sharks, *Prionace glauca* (L.), with implications for their conservation. *Journal of Fish Diseases* 25: 515-521.

Borucinska J, Martin J, Skomal G (2001) Peritonitis and pericarditis associated with gastric perforation by a retained fishing hook in a blue shark. *Journal of Aquatic Animal Health* 13: 347-354.

Bradshaw CJA, Fitzpatrick BM, Steinberg CC, Brook BW, Meekan MG (2008) Decline in whale shark size and abundance at Ningaloo Reef over the past decade: the world's largest fish is getting smaller. *Biological Conservation* 141: 1894-1905.

Brill R, Bushnell P, Schroff S, Seifert R, Galvin M (2008) Effects of anaerobic exercise accompanying catch-and-release fishing on blood-oxygen affinity of the sandbar shark (*Carcharhinus plumbeus*, Nardo). *Journal of Experimental Marine Biology and Ecology* 354: 132-143.

Brill RW (1996) Selective advantages conferred by the high performance physiology of tunas, billfishes, and dolphin fish. *Comparative Biochemistry and Physiology Part A: Physiology* 113: 3-15.

Brownscombe JW, Nowell L, Samson E, Danylchuk AJ, Cooke SJ (2014) Fishing-related stressors inhibit refuge-seeking behavior in released subadult Great Barracuda. *Transactions of the American Fisheries Society* 143: 613-617.

Bruce B (2014). Shark futures: A synthesis of available data on mako and porbeagle sharks in Australasian waters. Current status and future directions. Fisheries Research and Development Corporation (FRDC). CSIRO, pp 159.

Burns KM, Froeschke JT (2012) Survival of red grouper (*Epinephalus Morio*) and red snapper (*Lutjanus Campechanus*) caught on J-hooks and circle hooks in the florida recreational and recreational-for-hire fisheries. *Bulletin of Marine Science* 88: 633-646.

Cahill J (2013) Drifting and Berleying for Mako Sharks. *Hooked Up Magazine*. http://www.hookedupmagazine.com.au/how-to/drifting-and-berleying-for-mako-sharks/ Accessed: Feb, 2017.

Cailliet GM, Cavanagh RD, Kulka DW, Stevens JD, Soldo A, Clo S, Macias D, Baum JK, Kohin S, Duarte A, Holtzhausen JA, Acuna E, Amorim A, Domingo A (2009) *Isurus oxyrinchus*. In: The IUCN Red List of Threatened Species. Version 2014.2. www.iucnredlist.org Accessed: Oct, 2014.

Campana SE, Joyce W, Manning MJ (2009) Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. *Marine Ecology-Progress Series* 387: 241-253.

Campana SE, Marks L, Joyce W (2005) The biology and fishery of shortfin mako sharks (*Isurus oxyrinchus*) in Atlantic Canadian waters. *Fisheries Research* 73: 341-352.

Campana SE, Marks L, Joyce W, Kohler NE (2006) Effects of recreational and commercial fishing on blue sharks (*Prionace glauca*) in Atlantic Canada, with inferences on the North Atlantic population. *Canadian Journal of Fisheries and Aquatic Sciences* 63: 670-682.

Cardona-Pons F, Morales-Nin B, Sutton SG (2010) Scientists and recreational fishers communication manners and its efficiency. *Fisheries Research* 106: 575-578.

Cardona F, Morales-Nin B (2013) Anglers' perceptions of recreational fisheries and fisheries management in Mallorca. *Ocean & Coastal Management* 82: 146-150.

Carey FG, Teal JM (1969) Mako and porbeagle: warm-bodied sharks. *Comparative Biochemistry and Physiology* 28: 199-204.

Carruthers EH, Schneider DC, Neilson JD (2009) Estimating the odds of survival and identifying mitigation opportunities for common bycatch in pelagic longline fisheries. *Biological Conservation* 142: 2620-2630.

Caruso PG (2000). A comparison of catch and release mortality and wounding for striped bass (*Morone saxatilis*), captured with two baited hook types. *Completion Report for Job 12, Sportfisheries Research Project (F-57-R)*. Commonwealth of Massachusetts. Division of Marine Fisheries, pp 1-16.

Castro JI (2010) *The sharks of north America*. Oxford University Press, New York, USA.

Chandroo KP, Yue S, Moccia RD (2004) An evaluation of current perspectives on consciousness and pain in fishes. *Fish and Fisheries* 5: 281-295.

Chang J-H, Liu K-M (2009) Stock assessment of the shortfin mako shark (*Isurus oxyrinchus*) in the Northwest Pacific Ocean using per recruit and virtual population analyses. *Fisheries Research* 98: 92-101.

Chapin Iii FS, Carpenter SR, Kofinas GP, Folke C, Abel N, Clark WC, Olsson P, Smith DMS, Walker B, Young OR, Berkes F, Biggs R, Grove JM, Naylor RL, Pinkerton E, Steffen W, Swanson FJ (2010) Ecosystem stewardship: sustainability strategies for a rapidly changing planet. *Trends in Ecology & Evolution* 25: 241-249.

Chapter 2 High survivorship after catch and release fishing suggests physiological resilience in the endothermic shortfin mako shark (*Isurus oxyrinchus*), *Integrating Biological and Social Information to Inform Responsible Practices for Recreational Shark Fishing*.

Chapter 3 Understanding the catch and release behaviour of a specialised group of anglers, *Integrating Biological and Social Information to Inform Responsible Practices for Recreational Shark Fishing*.

Chapter 4 Explaining fishing behaviours with existing beliefs on sharks and their conservation, *Integrating Biological and Social Information to Inform Responsible Practices for Recreational Shark Fishing*.

Clarke S, Harley S, Hoyle S, Rice J (2011). An indicator-based analysis of key shark species based on data held by SPC-OFP. *WCPFC-SC7-2011/EB-WP-01, Western and Central Pacific Fisheries Commission*, Palikir, Federated States of Micronesia.

Clarke SC, Harley SJ, Hoyle SD, Rice JS (2013) Population Trends in Pacific Oceanic Sharks and the Utility of Regulations on Shark Finning. *Conservation Biology* 27: 197-209.

Claughton D (2014) Fisherman angered by NSW opposition election policy pitch for a Sydney marine park. ABC Rural, New South Wales Country Hour,. *ABC Rural*, . http://www.abc.net.au/news/2014-09-29/nsw-alp-sydney-marine-park-policy/5779390 Accessed: Oct, 2016.

Cliff G, Thurman GD (1984) Pathological and physiological effects of stress during capture and transport in the juvenile dusky shark, *Carcharhinus obscurus*. *Comparative Biochemistry and Physiology Part A: Physiology* 78: 167-173.

Coleman FC, Figueira WF, Ueland JS, Crowder LB (2004) The impact of United States recreational fisheries on marine fish populations. *Science* 305: 1958-1960.

Cooke SJ, Cowx IG (2004) The role of recreational fishing in global fish crises. *BioScience* 54: 857-859.

Cooke SJ, Cowx IG (2006) Contrasting recreational and commercial fishing: searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation* 128: 93-108.

Cooke SJ, Donaldson MR, O'Connor CM, Raby GD, Arlinghaus R, Danylchuk AJ, Hanson KC, Hinch SG, Clark TD, Patterson DA, Suski CD (2013) The physiological consequences of catch-and-release angling: perspectives on experimental design, interpretation, extrapolation and relevance to stakeholders. *Fisheries Management and Ecology* 20: 268-287.

Cooke SJ, Hogan ZS, Butcher PA, Stokesbury MJW, Raghavan R, Gallagher AJ, Hammerschlag N, Danylchuk AJ (2016) Angling for endangered fish: conservation problem or conservation action? *Fish and Fisheries* 17: 249-265.

Cooke SJ, Hogle WJ (2000) Effects of retention gear on the injury and short-term mortality of adult smallmouth bass. *North American Journal of Fisheries Management* 20: 1033-1039.

Cooke SJ, Nguyen VM, Murchie KJ, Danylchuk AJ, Suski CD (2012) Scientific and stakeholder perspectives on the use of circle hooks in recreational fisheries. *Bulletin of Marine Science* 88: 395-410.

Cooke SJ, Sneddon LU (2007) Animal welfare perspectives on recreational angling. *Applied Animal Behaviour Science* 104: 176-198.

Cooke SJ, Suski CD (2004) Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? *Aquatic Conservation - Marine and Freshwater Ecosystems* 14: 299-326.

Cooke SJ, Suski CD (2005) Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? *Biodiversity & Conservation* 14: 1195-1209.

Cooper AR, Morris S (1998) The blood respiratory, haematological, acid-base and ionic status of the Port Jackson shark, *Heterodontus portusjacksoni*, during recovery from anaesthesia and surgery: a comparison with sampling by direct caudal puncture. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 119: 895-903.

Cortés E, Arocha F, Beerkircher L, Carvalho F, Domingo A, Heupel M, Holtzhausen H, Santos MN, Ribera M, Simpfendorfer C (2010) Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. *Aquatic Living Resources* 23: 25-34.

Currie S (2011). Heat shock proteins and temperature. In Farrell AP ed, *Encyclopedia of Fish Physiology: From Genome to Environment* Vol. 3, Academic Press, San Diego, pp 1732-1737.

Currie S, Tufts BL, Moyes CD (1999) Influence of bioenergetic stress on heat shock protein gene expression in nucleated red blood cells of fish. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 276: R990-R996.

Danylchuk A, Suski C, Mandelman JW, Murchie K, Haak CR, Brooks AML, Cooke SJ (2014) Hooking injury, physiological status and short-term mortality of juvenile lemon sharks (*Negaprion bevirostris*) following catch-and-release recreational angling. *Conservation Physiology* 2: 1-10.

Danylchuk AJ, Cooke SJ (2011) Engaging the recreational angling community to implement and manage aquatic protected areas. *Conservation Biology* 25: 458-464.

Davenport MA, Leahy JE, Anderson DH, Jakes PJ (2007) Building trust in natural resource management within local communities: a case study of the Midewin National Tallgrass Prairie. *Environmental Management* 39: 353-368.

Davie P, Kopf R (2006) Physiology, behaviour and welfare of fish during recreational fishing and after release. *New Zealand Veterinary Journal* 54: 161-172.

Dawson CP, Wilkins BT (1981) Motivations of New York and Virginia marine boat anglers and their preferences for potential fishing constraints. *North American Journal of Fisheries Management* 1: 151-158.

De Faria F (2012) *Recreational Fishing of Sharks in the Great Barrier Reef World Herritage Area: Species Composition and Incidental Capture Stress*. Masters (research), James Cook University.

De Leeuw AD (1996) Contemplating the interests of fish. *Environmental Ethics* 18: 373-390.

Decker DJ, Krueger CC, Baer RA, Knuth BA, Richmond ME (1996) From clients to stakeholders: a philosophical shift for fish and wildlife management. *Human Dimensions of Wildlife* 1: 70-82.

Diggles BK, Cooke SJ, Rose JD, Sawynok W (2011) Ecology and welfare of aquatic animals in wild capture fisheries. *Reviews in Fish Biology and Fisheries* 21: 739-765.

Ditton RB (2002). A human dimensions perspective on catch-and-release fishing, *American Fisheries Society Symposium*, American Fisheries Society, pp 19-28.

Ditton RB, Loomis DK, Choi S (1992) Recreation specialization: re-conceptualization from a social worlds perspective. *Journal of Leisure Research* 24: 33-51.

Donaldson MR, Arlinghaus R, Hanson KC, Cooke SJ (2008) Enhancing catch-and-release science with biotelemetry. *Fish and Fisheries* 9: 79-105.

Dorow M, Arlinghaus R (2012) The relationship between personal commitment to angling and the opinions and attitudes of German anglers towards the conservation and management of the european eel Anguilla anguilla. *North American Journal of Fisheries Management* 32: 466-479.

DPIPWE (2016) Scalefish. Bag and Possession Limits. *Department of Primary Industries, Parks, Water and Environment, Tasmanian Government*, Tasmania, Australia. http://dpipwe.tas.gov.au/sea-fishing-aquaculture/recreational-fishing/catch-limits/possession-limits-scalefish Accessed: Dec, 2016.

Duffield JW, Merritt MF, Neher CJ (2007) Valuation and policy in Alaskan sport fisheries, *Recreational Fisheries*: Blackwell Publishing Ltd, pp 156-185.

Dulvy NK, Baum JK, Clarke S, Compagno LJV, Cortés E, Domingo A, Fordham S, Fowler S, Francis MP, Gibson C, Martínez J, Musick JA, Soldo A, Stevens JD, Valenti S (2008) You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18: 459-482.

Dunn OJ (1964) Multiple Comparisons Using Rank Sums. *Technometrics* 6: 241-252.

Epperly SP, Watson JW, Foster DG, Shah AK (2012) Anatomical hooking location and condition of animals captured with pelagic longlines: the grand banks experiments 2002-2003. *Bulletin of Marine Science* 88: 513-527.

Evans DH, Kormanik GA (1985) Urea efflux from the *Squalus acanthias* pup: the effect of stress. *Journal of Experimental Biology* 119: 375-379.

Falterman B, Graves JE (2002). A preliminary comparison of the relative mortality and hooking efficiency of circle and straight shank (" J") hooks used in the pelagic longline industry, *American Fisheries Society Symposium*, American Fisheries Society, pp 80-87.

FAO (1995). FAO code of conduct for responsible fisheries. FAO, Rome, Italy, pp 41.

FAO (2012). Recreational fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 13. FAO, Rome, Italy pp 176.

Fedler A, Ditton R (1986) A framework for understanding the consumptive orientation of recreational fishermen. *Environmental Management* 10: 221-227.

Fedler AJ (2001) *Defining Best Practices in Boating, Fishing, and Stewardship Education.* Recreational Boating & Fishing Foundation. Alexandria, VA. pp 187.

Fedler AJ (2002) To keep or release: understanding differences in angler behavior. In A. LJ, L. SA eds, *Catch and Release in Marine Recreational Fisheries - American Fisheries Society Symposium* Vol. 30: American Fisheries Society, pp 208-211.

Fenichel EP, Abbott JK, Huang B (2013) Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature. *Fish and Fisheries* 14: 137-157.

Ferretti F, Myers RA, Serena F, Lotze HK (2008) Loss of large predatory sharks from the Mediterranean Sea. *Conservation Biology* 22: 952-964.

Fisher MR (1997) Segmentation of the angler population by catch preference, participation, and experience: a management-oriented application of recreation specialization. *North American Journal of Fisheries Management* 17: 1-10.

Fisher MR, Ditton RB (1993) A social and economic characterization of the US Gulf of Mexico recreational shark fishery. *Marine Fisheries Review* 55: 21-27.

Flora DB, Curran PJ (2004) An empirical evaluation of alternative methods of estimation for confirmatory factor analysis with ordinal data. *Psychological Methods* 9: 466-491.

Fobert E, Meining P, Colotelo A, O'Connor C, Cooke SJ (2009) Cut the line or remove the hook? An evaluation of sublethal and lethal endpoints for deeply hooked bluegill. *Fisheries Research* 99: 38-46.

Francis M, Clarke SC, Griggs LH, Hoyle SD (2014). Indicator based analysis of the status of New Zealand blue, mako and porbeagle sharks. *New Zealand fisheries assessment report 2014/69*. Ministry for Primary Industries, New Zealand, pp 109.

Francis MP, Duffy C (2005) Length at maturity in three pelagic sharks (*Lamna nasus, Isurus oxyrinchus,* and *Prionace glauca*) from New Zealand. *Fishery Bulletin* 103: 489-500.

Frick LH, Reina RD, Walker TI (2010a) Stress related physiological changes and post-release survival of Port Jackson sharks (*Heterodontus portusjacksoni*) and gummy sharks (*Mustelus antarcticus*) following gill-net and longline capture in captivity. *Journal of Experimental Marine Biology and Ecology* 385: 29-37.

Frick LH, Walker TI, Reina RD (2010b) Trawl capture of Port Jackson sharks, *Heterodontus portusjacksoni*, and gummy sharks, *Mustelus antarcticus*, in a controlled setting: Effects of tow duration, air exposure and crowding. *Fisheries Research* 106: 344-350.

Frick LH, Walker TI, Reina RD (2012) Immediate and delayed effects of gill-net capture on acid-base balance and intramuscular lactate concentration of gummy sharks, *Mustelus antarcticus*. *Comparative Biochemistry and Physiology. Part A, Molecular & Integrative Physiology* 162: 88-93.

Frijlink S (2011) *A Socioeconomic Assessment of the Tasmanian Game Fishery*. PhD. Doctoral Thesis, University of Tasmania, Hobart.

Galeano D, Langenkamp D, Levantis C, Shafron W, Redmond I (2004). Economic value of charter and recreational fishing in Australia's eastern tuna and billfish fishery. *ABARE eReport*. Australian Government, Canberra, Australia, pp 42.

Gallagher A, Serafy J, Cooke S, Hammerschlag N (2014) Physiological stress response, reflex impairment, and survival of five sympatric shark species following experimental capture and release. *Marine Ecology-Progress Series* 496: 207-218.

Gallagher AJ, Cooke SJ, Hammerschlag N (2015) Risk perceptions and conservation ethics among recreational anglers targeting threatened sharks in the subtropical Atlantic. *Endangered Species Research* 29: 81-93.

Gallagher AJ, Hammerschlag N, Danylchuk AJ, Cooke SJ (2016) Shark recreational fisheries: Status, challenges, and research needs. *Ambio*: 1-14.

GFAA (2016) GFAA Code of Practice for a Responsible Gamefish Fishery. *Game Fishing Association Australia*. http://www.gfaa.asn.au/new/index.php/gfaa-information/gfaa-principles-code-of-practice Accessed: Feb, 2017.

GFAA (2017a) Angling Rules: Disqualifying Acts & Situations. *Game Fishing Association Australia*. http://www.gfaa.asn.au/new/index.php/rules-regulations-general/disqualifying-acts-situations Accessed: Feb, 2017.

GFAA (2017b) Line Class, All Tackle & Fly Categories. *Game Fishing Association Australia*. http://www.gfaa.asn.au/new/index.php/record-applications/line-class-all-tackle-fly Accessed: Feb, 2017.

GFAV (2016) GFAV - About Us. *Game Fishing Association of Victoria*. http://www.gfav.com.au/ Accessed: Feb, 2017.

Gibbs L, Warren A (2014). WA shark cull season ends, and ocean users don't want it to return, The Conversation, University of Wollongong, pp 1-3.

Gigliotti LM, Peyton RB (1993) Values and behaviors of trout anglers, and their attitudes toward fishery management, relative to membership in fishing organizations: a Michigan case study. *North American Journal of Fisheries Management* 13: 492-501.

Gingerich AJ, Cooke SJ, Hanson KC, Donaldson MR, Hasler CT, Suski CD, Arlinghaus R (2007) Evaluation of the interactive effects of air exposure duration and water temperature on the condition and survival of angled and released fish. *Fisheries Research* 86: 169-178.

Goodyear CP (2002). Factors affecting robust estimates of the catch-and-release mortality using pop-off tag technology, *American Fisheries Society Symposium*, American Fisheries Society, pp 172-179.

Graefe AR (1980) *The Relationship Between the Level of Participation and Selcted Aspects of Specialisation in Recreational Fishing.* Doctoral Thesis, A&M University, Texas, USA.

Graefe AR, Ditton RB (1997). Understanding catch and release behaviour among billfish anglers, *Proceedings of the annual Gulf and Caribbean Fisheries Institute* Vol. 49, pp 430-455.

Grambsch AE, Fisher MF (1991) Catch and release statistics for U.S. bass and trout anglers, *Creel and Angler Surveys in Fisheries Management - American Fisheries Society Symposium 12*: American Fisheries Society, pp 390-396.

Granek EF, Madin EMP, Brown MA, Figueira W, Cameron DS, Hogan Z, Kristianson G, De Villiers P, Williams JE, Post J, Zahn S, Arlinghaus R (2008) Engaging recreational fishers in management and conservation: global case studies. *Conservation Biology* 22: 1125-1134.

Graves JE, Horodysky AZ (2008) Does hook choice matter? Effects of three circle hook models on postrelease survival of white marlin. *North American Journal of Fisheries Management* 28: 471-480.

Graves JE, Luckhurst BE, Prince ED (2002) An evaluation of pop-up satellite tags for estimating postrelease survival of blue marlin (*Makaira nigricans*) from a recreational fishery. *Fishery Bulletin* 100: 134-142.

Gray SA, Jordan R (2010) Ecosystem-based angling: incorporating recreational anglers into ecosystem-based management. *Human Dimensions of Wildlife* 15: 233-246.

Grixti D, Conron SD, Jones PL (2007) The effect of hook/bait size and angling technique on the hooking location and the catch of recreationally caught black bream, *Acanthopagrus butcheri*. *Fisheries Research* 84: 338-344.

Harrison SA (2014) *Livelihood Strategies and Lifestyle Choices of Fishers Along the Mississippi Gulf Coast*. Ph.D. Doctoral Thesis, Mississippi State University.

Heard M, Sutton S, Rogers P, Huveneers C (2016) Actions speak louder than words: tournament angling as an avenue to promote best practice for pelagic shark fishing. *Marine Policy* 64: 168-173.

Heberer C, Aalbers SA, Bernal D, Kohin S, DiFiore B, Sepulveda CA (2010) Insights into catch-and-release survivorship and stress-induced blood biochemistry of common thresher sharks (*Alopias vulpinus*) captured in the southern California recreational fishery. *Fisheries Research* 106: 495-500.

Henry GW, Lyle JM (2003). National recreational and indigenous fishing survey. FRDC Project No. 99/158. Department of Agriculture, Fisheries and Forestry, Australian Government, Canberra, Australia, pp 188.

Heywood JL (2011) Institutional norms and evaluative standards for parks and recreation resources research, planning, and management. *Leisure Sciences* 33: 441-449.

Hickley P, Tompkins H (1998) *Recreational Fisheries: Social, Economic, and Management Aspects*. Oxford: Fishing News Books.

Hight BV, Holts D, Graham JB, Kennedy BP, Taylor V, Sepulveda CA, Bernal D, Ramon D, Rasmussen LEL, Lai NC (2007) Plasma catecholamine levels as indicators of the post-release survivorship of juvenile pelagic sharks caught on experimental drift longlines in the Southern California Bight. *Marine and Freshwater Research* 58: 145-151.

Hilborn R, Fulton EA, Green BS, Hartmann K, Tracey SR, Watson RA (2015) When is a fishery sustainable? *Canadian Journal of Fisheries and Aquatic Sciences* 72: 1433-1441.

Hoenig JM, Gruber SH (1990). Life-history patterns in the elasmobranchs: implications for fisheries management. *Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of the Fisheries. Proceedings of the Second United States–Japan Workshop East–West Center. NOAA Technical Report NMFS*, Honolulu, Hawaii, pp 518-534.

Hoffmayer ER, Hendon JM, Parsons GR (2012) Seasonal modulation in the secondary stress response of a carcharhinid shark, *Rhizoprionodon terraenovae*. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 162: 81-87.

Hoffmayer ER, Parsons GR (2001) The physiological response to capture and handling stress in the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*. *Fish Physiology and Biochemistry* 25: 277-285.

Hu L-T, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling* 6: 1-55.

Hunt L, Haider W, Armstrong K (2002) Understanding the fish harvesting decisions by anglers. *Human Dimensions of Wildlife* 7: 75-89.

Hunt LM, Sutton SG, Arlinghaus R (2013) Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology* 20: 111-124.

Huntingford F, Adams C, Braithwaite VA, Kadri S, Pottinger TG, Sandoe P, Turnbull JF (2007) The implications of a feelings-based approach to fish welfare: a reply to Arlinghaus et al. *Fish and Fisheries* 8: 277-280.

Huntingford FA, Adams C, Braithwaite VA, Kadri S, Pottinger TG, Sandøe P, Turnbull JF (2006) Current issues in fish welfare. *Journal of Fish Biology* 68: 332-372.

Hutchinson MR, Itano DG, Muir JA, Holland KN (2015) Post-release survival of juvenile silky sharks captured in a tropical tuna purse seine fishery. *Marine Ecology Progress Series* 521: 143-154.

Hutt CP, Bettoli PW (2007) Preferences, specialization, and management attitudes of trout anglers fishing in Tennessee tailwaters. *North American Journal of Fisheries Management* 27: 1257-1267.

Hyatt MW, Anderson PA, O'Donnell PM, Berzins IK (2012) Assessment of acid–base derangements among bonnethead (*Sphyrna tiburo*), bull (*Carcharhinus leucas*), and lemon (*Negaprion brevirostris*) sharks from gillnet and longline capture and handling methods. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 162: 113-120.

Jensen OP, Gilroy DJ, Hogan Z, Allen BC, Hrabik TR, Weidel BC, Chandra S, Vander Zanden MJ (2009) Evaluating recreational fisheries for an endangered species: a case study of taimen, Hucho taimen, in Mongolia. *Canadian Journal of Fisheries and Aquatic Sciences* 66: 1707-1718.

Johnston FD, Beardmore B, Arlinghaus R (2014) Optimal management of recreational fisheries in the presence of hooking mortality and noncompliance - predictions from a bioeconomic model incorporating a mechanistic model of angler behavior. *Canadian Journal of Fisheries and Aquatic Sciences* 72: 37-53.

Kaplan IM, McCay BJ (2004) Cooperative research, co-management and the social dimension of fisheries science and management. *Marine Policy* 28: 257-258.

Kellert SR (1985) Public perceptions of predators, particularly the wolf and coyote. *Biological Conservation* 31: 167-189.

Kerstetter DW, Graves JE (2006) Survival of white marlin (*Tetrapturus albidus*) released from commercial pelagic longline gear in the western North Atlantic. *Fishery Bulletin* 104: 434-444.

Kieffer J, Currie S, Tufts B (1994) Effects of environmental temperature on the metabolic and acid-base responses of rainbow trout to exhaustive exercise. *Journal of Experimental Biology* 194: 299-317.

Kieffer JD (2000) Limits to exhaustive exercise in fish. *Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology* 126: 161-179.

Kinney M, Wells R, Kohin S (2016) Oxytetracycline age validation of an adult shortfin mako shark *Isurus oxyrinchus* after 6 years at liberty. *Journal of Fish Biology* 89: 1828-1833.

Kiyota M, Nakano H (2000) Validation of shark catch data of the logbook records in the Japanese longline fishery in the Atlantic Ocean. *ICCAT Collective Volume of Scientific Papers* 51: 1776-1783.

Kneebone J, Chisholm J, Bernal D, Skomal G (2013) The physiological effects of capture stress, recovery, and post-release survivorship of juvenile sand tigers (*Carcharias taurus*) caught on rod and reel. *Fisheries Research* 147: 103-114.

Knopf RC, Driver B, Bassett JR (1973). Motivations for fishing, *Transactions of the North American Wildlife and Natural Resources Conference* Vol. 38, pp 191-204.

Kolhatkar A, Robertson CE, Thistle ME, Gamperl AK, Currie S (2014) Coordination of chemical (trimethylamine oxide) and molecular (heat shock protein 70) chaperone responses to heat stress in elasmobranch red blood cells. *Physiological and Biochemical Zoology* 87: 652-662.

Korkmaz S, Goksuluk D, Zararsiz G (2014) MVN: an R package for assessing multivariate normality. *The R Journal* 6: 151-162.

Krouwer JS (2008) Why Bland–Altman plots should use X, not (Y+X)/2 when X is a reference method. *Statistics in Medicine* 27: 778-780.

Kyle G, Norman W, Jodice L, Graefe A, Marsinko A (2007) Segmenting anglers using their consumptive orientation profiles. *Human Dimensions of Wildlife* 12: 115-132.

Lantz B (2013) The impact of sample non-normality on ANOVA and alternative methods. *British Journal of Mathematical and Statistical Psychology* 66: 224-244.

Leary S, Underwood W, Anthony R, Cartner S, Corey D, Grandin T, Greenacre CB, Gwaltney-Bran S, McCrackin MA, Meyer R (2013). AVMA guidelines for the euthanasia of animals: 2013 edition, *American Veterinary Medical Association*, Schaumburg, Illinois, USA.

LeBlanc S, Höglund E, Gilmour KM, Currie S (2012) Hormonal modulation of the heat shock response: insights from fish with divergent cortisol stress responses. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology* 302: R184-R192.

Lennox R, Whoriskey K, Crossin GT, Cooke SJ (2015) Influence of angler hook-set behaviour relative to hook type on capture success and incidences of deep hooking and injury in a teleost fish. *Fisheries Research* 164: 201-205.

Lewin W-C, Arlinghaus R, Mehner T (2006) Documented and potential biological impacts of recreational fishing: insights for management and conservation. *Reviews in Fisheries Science* 14: 305-367.

Likert R (1932) A technique for the measurement of attitudes. *Archives of Psychology* 140: 1-55.

Lowther A, Liddel M (2014). Fisheries of the United States 2013. Current Fishery Statistics No. 2013. *National Marine Fisheries Service Office of Science and Technology*, Silver Spring, Maryland, USA.

Lyle JM, Stark KE, Tracey SR (2014). 2012/13 Survey of recreational fishing in Tasmania. *Fishwise Community Grants Final Report*. Institute for Marine and Antarctic Studies, Hobart, Tasmania.

Lynch A-MJ, Sutton SG, Simpfendorfer CA (2010) Implications of recreational fishing for elasmobranch conservation in the Great Barrier Reef Marine Park. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20: 312-318.

MacLellan RJ, Tunnah L, Barnett D, Wright PA, MacCormack T, Currie S (2015) Chaperone roles for TMAO and HSP70 during hyposmotic stress in the spiny dogfish shark (*Squalus acanthias*). *Journal of Comparative Physiology Part B: Biochemical, Systemic, and Environmental Physiology* 185: 729-740.

Mandelman JW, Cooper PW, Werner TB, Lagueux KM (2008) Shark bycatch and depredation in the U.S. Atlantic pelagic longline fishery. *Reviews in Fish Biology and Fisheries* 18: 427-442.

Mandelman JW, Farrington MA (2007) The physiological status and mortality associated with otter-trawl capture, transport, and captivity of an exploited elasmobranch, *Squalus acanthias*. *ICES Journal of Marine Science* 64: 122-130.

Mandelman JW, Skomal GB (2009) Differential sensitivity to capture stress assessed by blood acid-base status in five carcharhinid sharks. *Journal of Comparative Physiology Part B: Biochemical Systemic and Environmental Physiology* 179: 267-277.

Manire C, Hueter R, Hull E, Spieler R (2001) Serological changes associated with gill-net capture and restraint in three species of sharks. *Transactions of the American Fisheries Society* 130: 1038-1048.

Mapleston A, Welch D, Begg GA, McLennan M, Mayer D, Brown I (2008) Effect of changes in hook pattern and size on catch rate, hooking location, injury and bleeding for a number of tropical reef fish species. *Fisheries Research* 91: 203-211.

Marshall H, Field L, Afiadata A, Sepulveda C, Skomal G, Bernal D (2012) Hematological indicators of stress in longline-captured sharks. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 162: 121-129.

Martin CL, Momtaz S, Jordan A, Moltschaniwskyj NA (2016) Exploring recreational fishers' perceptions, attitudes, and support towards a multiple-use marine protected area six years after implementation. *Marine Policy* 73: 138-145.

Mc Phee D, Leadbitter D, Skilleter G (2002) Swallowing the bait: is recreational fishing in Australia ecologically sustainable? *Pacific conservation biology* 8: 40-51.

McClellan Press K, Mandelman J, Burgess E, Cooke SJ, Nguyen VM, Danylchuk AJ (2016) Catching sharks: recreational saltwater angler behaviours and attitudes regarding shark encounters and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 26: 689-702.

McClenachan L (2009) Documenting Loss of Large Trophy Fish from the Florida Keys with Historical Photographs. *Conservation Biology* 23: 636-643.

McClymont J (2007) Shark mayhem - makos, gummies and a great white! . *Fishing Monthly Magazine*. http://www.fishingmonthly.net.au/Articles/Display/2780-Shark-mayhem--makos-gummies-and-a-great-white Accessed: Feb, 2017.

McEvEdy C, Jones R (1978) *Atlas of World Population History*. Penguin Books Ltd, Harmondsworth, Middlesex, England..

McPhee DP, Leadbitter D, Skilleter GA (2002) Swallowing the bait: is recreational fishing in Australia ecologically sustainable. *Pacific Conservation Biology* 8: 40-51.

Meka JM, McCormick SD (2005) Physiological response of wild rainbow trout to angling: impact of angling duration, fish size, body condition, and temperature. *Fisheries Research* 72: 311-322.

Mindrila D (2010) Maximum likelihood (ML) and diagonally weighted least squares (DWLS) estimation procedures: a comparison of estimation bias with ordinal and multivariate non-normal data. *International Journal of Digital Society* 1: 60-66.

Mladineo I, Block BA (2009) Expression of Hsp70, Na+/K+ ATP-ase, HIF-1α, IL-1β and TNF-α in captive Pacific bluefin tuna (*Thunnus orientalis*) after chronic warm and cold exposure. *Journal of Experimental Marine Biology and Ecology* 374: 51-57.

Moeller GH, Engelken JH (1972) What fishermen look for in a fishing experience. *The Journal of Wildlife Management* 36: 1253-1257.

Mollet HF, Cliff G, Pratt HL, Stevens JD (2000) Reproductive biology of the female shortfin mako, *Isurus oxyrinchus* Rafinesque, 1810, with comments on the embryonic development of lamnoids. *Fishery Bulletin* 98: 299-318.

Morgan A, Burgess GH (2007) At-vessel fishing mortality for six species of sharks caught in the Northwest Atlantic and Gulf of Mexico. *Gulf and Caribbean Research* 19: 123-129.

Moyes CD, Fragoso N, Musyl MK, Brill RW (2006) Predicting postrelease survival in large pelagic fish. *Transactions of the American Fisheries Society* 135: 1389-1397.

Muoneke MI, Childress WM (1994) Hooking mortality: a review for recreational fisheries. *Reviews in Fisheries Science* 2: 123-156.

Murua H, Cohelo R, Neves M, Arrizabalaga H, Yokawa K, Romanov E, Zhu J, Kim Z, Bach P, Chavance P (2012) Preliminary Ecological Risk Assessment (ERA) for shark species caught in fisheries managed by the Indian Ocean Tuna Commission (IOTC). *IOTC Techical Paper* 1: 1-26.

Musick JA, Burgess G, Cailliet G, Camhi M, Fordham S (2000) Management of sharks and their relatives (Elasmobranchii). *Fisheries* 25: 9-13.

Muter BA, Gore ML, Gledhill KS, Lamont C, Huveneers C (2013) Australian and U.S. news media portrayal of sharks and their conservation. *Conservation Biology* 27: 187-196.

Myers RA, Baum JK, Shepherd TD, Powers SP, Peterson CH (2007) Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science* 315: 1846-1850.

Neff C (2015) The Jaws effect: how movie narratives are used to influence policy responses to shark bites in Western Australia. *Australian Journal of Political Science* 50: 114-127.

Neff CL, Yang JY (2013) Shark bites and public attitudes: policy implications from the first before and after shark bite survey. *Marine Policy* 38: 545-547.

Nielsen LA (1999) History of inland fisheries management in North America. In Kohler CC, Hubert WA eds, *Inland fisheries management in North America, 2nd edition.*, Bethesda, Maryland, USA: American Fisheries Society, pp 3-30.

NPSGFC (2016) Newcastle and Port Stephens Game Fish Club History. *Newcastle & Port Stephens Game Fish Club*. http://www.npsgfc.com/about-us Accessed: Apr, 2016.

NSW Government (2016) Saltwater bag and size limits. *Department of Primary Industries*. http://www.dpi.nsw.gov.au/fishing/recreational/fishing-rules-and-regs/saltwater-bag-and-size-limits Accessed: Apr, 2016.

NSWGFA (2016) New South Wales Game Fishing Association History. *New South Wales Game Fishing Association*. http://www.nswgfa.com.au/history.php# Accessed: Apr, 2016.

O'Bryhim J (2009) *Public Knowledge, Attitudes, and Behavior Towards Sharks and Shark Conservation*. Master of Science. Masters Thesis, George Mason University, Fairfax, Virginia, USA.

O'Bryhim JR, Parsons ECM (2015) Increased knowledge about sharks increases public concern about their conservation. *Marine Policy* 56: 43-47.

Oh C-O, Ditton RB (2006) Using Recreation Specialization to Understand Multi-Attribute Management Preferences. *Leisure Sciences* 28: 369-384.

Pacheco JC, Kerstetter DW, Hazin FH, Hazin H, Segundo RSSL, Graves JE, Carvalho F, Travassos PE (2011) A comparison of circle hook and J hook performance in a western equatorial Atlantic Ocean pelagic longline fishery. *Fisheries Research* 107: 39-45.

Peres M, Vooren C (1991) Sexual development reproductive cycle, and fecundity of the school shark *Galeorhinus galeus* off southern Brazil. *Fishery Bulletin* 89: 655-667.

Philpott R (2002) Why sharks may have nothing to fear more than fear itself: an analysis of the effect of human attitudes on the conservation of the great white shark. *Colorado Journal of International Environmental Law and Policy* 13: 445-472.

Pohlert T (2014) The pairwise multiple comparison of mean ranks package (PMCMR), R package. https://cran.r-project.org/web/packages/PMCMR/vignettes/PMCMR.pdf Accessed: Oct, 2016.

Poli BM, Parisi G, Scappini F, Zampacavallo G (2005) Fish welfare and quality as affected by pre-slaughter and slaughter management. *Aquaculture International* 13: 29-49.

Policansky D (2002) Catch-and-Release recreational: a historical perspective. In Pitcher TJ, Hollingworth CE eds, *Recreational Fisheries: Ecological, Economic and Social Evaluation*: Oxford: Blackwell Science, pp 74-93.

Post JR, Sullivan M, Cox S, Lester NP, Walters CJ, Parkinson EA, Paul AJ, Jackson L, Shuter BJ (2002) Canada's recreational fisheries: the invisible collapse? *Fisheries* 27: 6-17.

Prayaga P, Rolfe J, Stoeckl N (2010) The value of recreational fishing in the Great Barrier Reef, Australia: a pooled revealed preference and contingent behaviour model. *Marine Policy* 34: 244-251.

Priede IG (1985) Metabolic scope in fishes. In Tytler P, Calow P eds, *Fish Energetics: New perspectives*, London, UK: Croom-Helm, pp 33–64.

Prince ED, Ortiz M, Venizelos A (2002) A comparison of circle hook and "J" hook performance in recreational catch-and-release fisheries for billfish. In Lucy JA, Studholme AL eds, *Catch and Release in Marine Recreational Fisheries - American Fisheries Society Symposium* Vol. 30, pp 66-79.

R Core Team (2014) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Raby GD, Packer JR, Danylchuk AJ, Cooke SJ (2014) The understudied and underappreciated role of predation in the mortality of fish released from fishing gears. *Fish and Fisheries* 15: 489-505.

Recfish Australia (2010). A national code of practice for recreational and sport fishing, *Department of Agriculture, Fisheries and Forestry, Australian Government*, Canberra, Australia, pp 1-6.

Reeves KA, Bruesewitz RE (2007) Factors influencing the hooking mortality of walleyes caught by recreational anglers on Mille Lacs, Minnesota. *North American Journal of Fisheries Management* 27: 443-452.

Renshaw GMC, Kutek AK, Grant GD, Anoopkumar-Dukie S (2012) Forecasting elasmobranch survival following exposure to severe stressors. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 162: 101-112.

Rice PH, Serafy JE, Snodgrass D, Prince ED (2012) Performance of non-offset and 10° offset 18/0 circle hooks in the United States pelagic longline fishery. *Bulletin of Marine Science* 88: 571-587.

Richards J, Heigenhauser G, Wood C (2003) Exercise and recovery metabolism in the pacific spiny dogfish (*Squalus acanthias*). *Journal of Comparative Physiology Part B: Biochemical, Systemic, and Environmental Physiology* 173: 463-474.

Roberts RJ, Agius C, Saliba C, Bossier P, Sung YY (2010) Heat shock proteins (chaperones) in fish and shellfish and their potential role in relation to fish health: a review. *Journal of Fish Diseases* 33: 789-801.

Rogers P, Bailleul F (2015). Innovative ways to ensure the future sustainability of the recreational fishery for shortfin makos in Victoria. *The State of Victoria, Department of Economic Development, Jobs, Transport & Resources Recreational Fishing Grants Program Research Report*. SARDI. South Australian Research and Development Institute (Aquatic Sciences). SARDI Publication No. F2015/000618-1, SARDI Research Report Series No. 872, Adelaide, Australia, pp 60.

Rogers P, Corrigan S, Lowther A (2015). Using satellite tagging and molecular techniques to improve the ecologically sustainable fisheries management of shortfin makos (*Isurus oxyrinchus*) in the Australasian region. *FRDC Tactical Research Fund*. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, Australia, pp 97.

Rosseel Y (2012) lavaan: An R package for structural equation modeling. *Journal of Statistical Software* 48: 1-36.

Roy Morgan Research (2003). National strategy for the survival of released line caught fish: released fish survival national survey report. *InfoFish*. Australian Government, Canberra, Australia, pp 80.

Ryan K, Hall N, Lai E, Smallwood C, Taylor S, Wise B (2015). State-wide survey of boat-based recreational fishing in Western Australia 2013/14. Fisheries Research Report No. 268. Department of Fisheries, Western Australia, pp 208.

Salz RJ, Loomis DK (2005) Recreation specialization and anglers' attitudes towards restricted fishing areas. *Human Dimensions of Wildlife* 10: 187-199.

Salz RJ, Loomis DK, Finn KL (2001) Development and validation of a specialization index and testing of specialization theory. *Human Dimensions of Wildlife* 6: 239-258.

Schill DJ (1996) Hooking mortality of bait-caught rainbow trout in an Idaho trout stream and a hatchery: implications for special-regulation management. *North American Journal of Fisheries Management* 16: 348-356.

Schreiber JB, Nora A, Stage FK, Barlow EA, King J (2006) Reporting structural equation modeling and confirmatory factor analysis results: a review. *The Journal of Educational Research* 99: 323-338.

Schroeder DM, Love MS (2002). Recreational fishing and marine fish populations in California. *California Cooperative Oceanic Fisheries Investigations Report 43*. Marine Science Institute, University of California, Santa Barbara, California, USA, pp 182-190.

Schroeder SA, Fulton DC (2016) Voice, perceived fairness, agency trust, and acceptance of management decisions among Minnesota anglers. *Society & Natural Resources* 30: 569-584.

Schuhmann PW, Schwabe KA (2004) An analysis of congestion measures and heterogeneous angler preferences in a random utility model of recreational fishing. *Environmental and Resource Economics* 27: 429-450.

Semba Y, Aoki I, Yokawa K (2011) Size at maturity and reproductive traits of shortfin mako, *Isurus oxyrinchus*, in the western and central North Pacific. *Marine and Freshwater Research* 62: 20-29.

Sepulveda C, Heberer C, Aalbers S, Spear N, Kinney M, Bernal D, Kohin S (2015) Post-release survivorship studies on common thresher sharks (*Alopias vulpinus*) captured in the southern California recreational fishery. *Fisheries Research* 161: 102-108.

Sepulveda CA, Graham JB, Bernal D (2007) Aerobic metabolic rates of swimming juvenile mako sharks, *Isurus oxyrinchus*. *Marine biology* 152: 1087-1094.

SGFC (2014) Sydney Game Fishing Club History. *Sydney Game Fishing Club*. http://sgfc.com.au/history/ Accessed: Apr, 2016.

Shelby B, Vaske JJ (1991) Resource and activity substitutes for recreational salmon fishing in New Zealand. *Leisure Sciences* 13: 21-32.

Shiffman DS (2014) More large sharks were killed by recreational anglers than commercial fishermen in the US last year. http://www.southernfriedscience.com/more-large-sharks-were-killed-by-recreational-anglers-than-commercial-fishermen-in-the-u-s-last-year/ Accessed: Jan, 2017.

Shiffman DS, Gallagher AJ, Wester J, Macdonald CC, Thaler AD, Cooke SJ, Hammerschlag N (2014) Trophy fishing for species threatened with extinction: a way forward building on a history of conservation. *Marine Policy* 50, Part A: 318-322.

Shiffman DS, Gallagher AJ, Wester J, Macdonald CC, Thaler AD, Cooke SJ, Hammerschlag N (2015) A letter of clarification from the authors of "trophy fishing for species threatened with extinction". *Marine Policy* 53: 213-214.

Shrestha RK, Seidl AF, Moraes AS (2002) Value of recreational fishing in the Brazilian Pantanal: a travel cost analysis using count data models. *Ecological Economics* 42: 289-299.

Skomal G, Babcock EA, Pikitch EK (2008) Case study: blue and mako shark catch rates in US Atlantic recreational fisheries as potential indices of abundance. In Camhi M, Pikitch E, Babcock E eds, *Sharks of the Open Ocean: Biology, Fisheries and Conservation*, Oxford, UK: Blackwell Publishing, pp 205-212.

Skomal GB (2007) Evaluating the physiological and physical consequences of capture on post-release survivorship in large pelagic fishes. *Fisheries Management and Ecology* 14: 81-89.

Skomal GB, Bernal D (2010) Physiological responses to stress in sharks. In Carrier J, Musick J, Heithaus M eds, *Sharks and Their Relatives II: Biodiversity, Adaptive Physiology, and Conservation*, Boca Raton: CRC Press, pp 459–490.

Skomal GB, Chase BC, Prince ED (2002) A comparison of circle hook and straight hook performance in recreational fisheries for juvenile Atlantic bluefin tuna. In Lucy JA, Studholme AL eds, *Catch and Release in Marine Recreational Fisheries - American Fisheries Society Symposium* Vol. 30, pp 57-65.

Skomal GB, Mandelman JW (2012) The physiological response to anthropogenic stressors in marine elasmobranch fishes: a review with a focus on the secondary response. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 162: 146-155.

Smith A, Welch DJ, Donnelly R, Kelley R (2016). A review of the national recreational fishing code of practice. Reef Ecologic Pty Ltd, Townsville, Queensland, Australia, pp 32.

Sneddon LU (2006) Ethics and welfare: pain perception in fish. *Bulletin of the European Association of Fish Pathologists* 26: 6-10.

Stensland S, Aas Ø, Mehmetoglu M (2013) The Influence of norms and consequences on voluntary catch and release angling behavior. *Human Dimensions of Wildlife* 18: 373-385.

Stevens JD (1984) Biological observations on sharks caught by sport fisherman of New South Wales. *Marine and Freshwater Research* 35: 573-590.

Stevens JD (1992) Blue and mako shark by-catch in the Japanese longline fishery off south-eastern Australia. *Marine and Freshwater Research* 43: 227-236.

Stevens JD (2008) The biology and ecology of the shortfin mako shark, *Isurus oxyrinchus*. In Camhi M, Pikitch E, Babcock E eds, *Sharks of the Open Ocean: Biology, Fisheries and Conservation*, Oxford, UK: Blackwell Publishing, pp 87-94.

Stevens JD, Bonfil R, Dulvy NK, Walker PA (2000) The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science* 57: 476-494.

Stokesbury MJW, Neilson JD, Susko E, Cooke SJ (2011) Estimating mortality of Atlantic bluefin tuna (*Thunnus thynnus*) in an experimental recreational catch-and-release fishery. *Biological Conservation* 144: 2684-2691.

Sutton S (2003) Personal and situational determinants of catch-and-release choice of freshwater anglers. *Human Dimensions of Wildlife* 8: 109-126.

Sutton SG (2001) *Understanding the catch and release behaviour of recreational anglers*. PhD. Doctoral Thesis, Texas A&M University, Texas, USA.

Sutton SG, Ditton RB (2001) Understanding catch-and-release behavior among U.S. Atlantic bluefin tuna anglers. *Human Dimensions of Wildlife* 6: 49-66.

Sutton SG, Ditton RB (2005) The substitutability of one type of fishing for another. *North American Journal of Fisheries Management* 25: 536-546.

TGFA (2013) TGFA History. *Tasmanian Game Fishing Association*. http://www.tgfa.asn.au/ Accessed: Apr, 2016.

TGFA (2016) List of Tasmanian Game Fishing Tournaments. *Tasmanian Game Fishing Association*. http://www.tgfa.asn.au/tourn_data.html Accessed: Aug, 2016.

Tracey S, Buxton C, Gardner C, Green B, Hartmann K, Haward M, Jabour J, Lyle J, McDonald J (2013a) Super trawler scuppered in Australian fisheries management reform. *Fisheries* 38: 345-350.

Tracey S, Lyle JM, Ewing G, Hartmann K, Mapleston A (2013b). Offshore recreational fishing in Tasmania 2011/12. DPIPWE Fishwise. Institute for Marine and Antarctic Studies, Hobart, Tasmania, Australia.

Tracey SR, Hartmann K, Leef M, McAllister J (2016) Capture-induced physiological stress and postrelease mortality for Southern bluefin tuna (*Thunnus maccoyii*) from a recreational fishery. *Canadian Journal of Fisheries and Aquatic Sciences* 73: 1547-1556.

Treberg JR, Speers-Roesch B, Piermarini PM, Ip YK, Ballantyne JS, Driedzic WR (2006) The accumulation of methylamine counteracting solutes in elasmobranchs with differing levels of urea: a comparison of marine and freshwater species. *Journal of experimental biology* 209: 860-870.

Turner JD, Wood CM, Clark D (1983) Lactate and proton dynamics in the rainbow trout (*Salmo gairdneri*). *Journal of experimental biology* 104: 247-268.

Victorian State Government (2016) Catch Limits and Closed Seasons. *Victorian State Government Fisheries*, Victoria, Australia. http://agriculture.vic.gov.au/fisheries/recreational-fishing/recreational-fishing-guide/catch-limits-and-closed-seasons/marine-and-estuarine-scale-fish Accessed: Apr, 2016.

Villalobos ARA, Renfro JL (2007) Trimethylamine oxide suppresses stress-induced alteration of organic anion transport in choroid plexus. *Journal of Experimental Biology* 210: 541-552.

Voyer M, Gladstone W, Goodall H (2014) Understanding marine park opposition: the relationship between social impacts, environmental knowledge and motivation to fish. *Aquatic Conservation: Marine and Freshwater Ecosystems* 24: 441-462.

Wainwright L (2015) *Stakeholder Power Dynamics in Environmental Decision Making: A Case Study of the 2012 FVMargiris 'Super Trawler'Fishing Dilemma in Australia*. Masters Thesis, Uppsala University, Uppsala, Sweden.

Walker TI (1999) Can shark resources be harvested sustainably? A question revisited with a review of shark fisheries. *Marine and Freshwater Research* 49: 553-572.

Wallmo K, Gentner B (2008) Catch-and-release fishing: a comparison of intended and actual behavior of marine anglers. *North American Journal of Fisheries Management* 28: 1459-1471.

Walsh PJ, Kajimura M, Mommsen TP, Wood CM (2006) Metabolic organization and effects of feeding on enzyme activities of the dogfish shark (*Squalus acanthias*) rectal gland. *Journal of experimental biology* 209: 2929-2938.

Watson RR, Dickson KA (2001) Enzyme activities support the use of liver lipid–derived ketone bodies as aerobic fuels in muscle tissues of active sharks. *Physiological and Biochemical Zoology* 74: 273-282.

Wells R, McIntyre R, Morgan A, Davie P (1986) Physiological stress responses in big gamefish after capture: observations on plasma chemistry and blood factors. *Comparative Biochemistry and Physiology Part A: Comparative Physiology* 84: 565-571.

Wells R, Smith SE, Kohin S, Freund E, Spear N, Ramon DA (2013) Age validation of juvenile shortfin mako (*Isurus oxyrinchus*) tagged and marked with oxytetracycline off southern California. *Fishery Bulletin* 111: 147-160.

Wells RMG, Davie PS (1985) Oxygen binding by the blood and hematological effects of capture stress in two big gamefish: Mako shark and striped marlin. *Comparative Biochemistry and Physiology Part A: Physiology* 81: 643-646.

Wilde GR, Riechers RK, Ditton RB (1998) Differences in attitudes, fishing motives, and demographic characteristics between tournament and nontournament black bass anglers in Texas. *North American Journal of Fisheries Management* 18: 422-431.

Wilson SM, Raby GD, Burnett NJ, Hinch SG, Cooke SJ (2014) Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. *Biological Conservation* 171: 61-72.

Wood AD, Collie JS, Kohler NE (2007) Estimating survival of the shortfin mako *Isurus oxyrinchus* (Rafinesque) in the north-west Atlantic from tag-recapture data. *Journal of Fish Biology* 71: 1679-1695.

Wood CM, Turner JD, Graham MS (1983) Why do fish die after severe exercise? *Journal of Fish Biology* 22: 189-201.

Wood CM, Walsh PJ, Kajimura M, McClelland GB, Chew SF (2010) The influence of feeding and fasting on plasma metabolites in the dogfish shark (*Squalus acanthias*). *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 155: 435-444.

Worm B, Davis B, Kettemer L, Ward-Paige CA, Chapman D, Heithaus MR, Kessel ST, Gruber SH (2013) Global catches, exploitation rates, and rebuilding options for sharks. *Marine Policy* 40: 194-204.

Yancey PH, Somero GN (1979) Counteraction of urea destabilization of protein structure by methylamine osmoregulatory compounds of elasmobranch fishes. *Biochemical Journal* 183: 317-323.

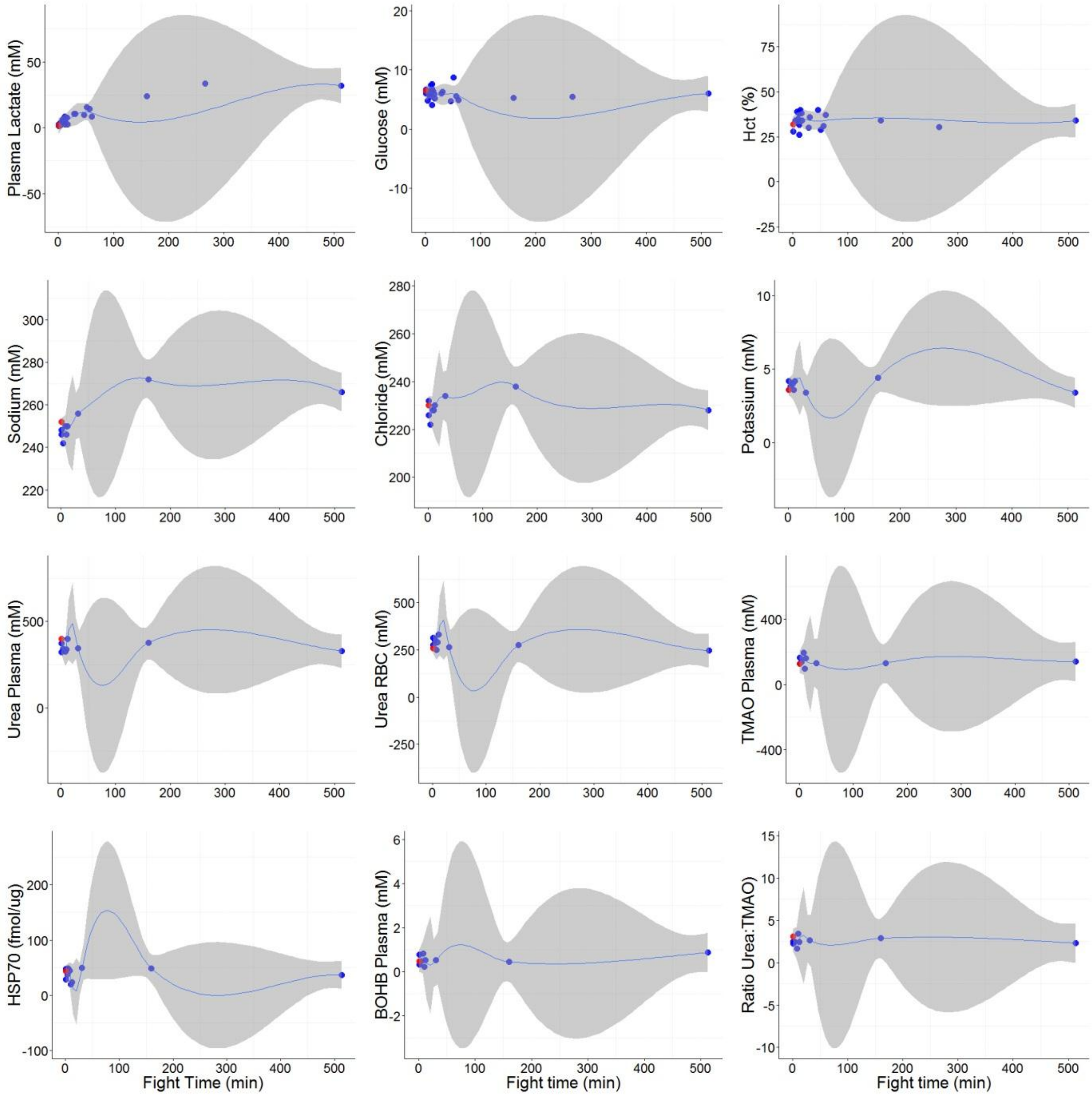
Zischke MT, Griffiths SP, Tibbetts IR (2012) Catch and effort from a specialised recreational pelagic sport fishery off eastern Australia. *Fisheries Research* 127: 61-72.

Zuur AF (2012) *Beginner's guide to generalized additive models with R*. Highland Statistics Ltd, Newburgh, UK.

Zuur AF, Ieno EN, Elphick CS (2010) A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution* 1: 3-14.

Zuur AF, Ieno EN, Walker NJ, Saveliev AA, Smith GM (2009) *Mixed effects models and extensions in ecology with R* Springer, New York, USA.

Appendix I
Supplementary Data for Chapter 2



Supplementary Figure 1: Loess smoothing functions (blue line) showing the relationship and 95% confidence intervals (grey shading) between fight time (minutes) and each of the measured blood parameter all sharks. Tagged individuals (n = 27) are overlayed on the function with blue dots representing survivors and red dots indicating mortalities. The spread of confidence intervals beyond 70 mins illustrates the unreliability associated with including these extreme data in the final GAMs.

Appendix II
Questionnaire Cover Letter

Survey of Australian Mako Fishers

Dear Angler

You are invited to participate in a survey about mako fishing. The survey is designed to gather information on the fishing Practices and attitudes of mako anglers in south eastern Australia. If you have been mako fishing in any of these states in the past 12 months, please consider completing this survey.

We understand your time is valuable and have tried to make the questionnaire easy to follow and complete, while still being detailed enough to address our research questions. Other information about the survey and how to enter the draw for prizes is explained below.

Who is conducting this research?
The survey is being conducted by the Institute for Marine and Antarctic Studies (IMAS) as part of a PhD project. The project is focused on catch and release fishing for mako sharks and is joint funded by Fishwise Community Grants (Tasmania) and a Holsworth Wildlife Research Endowment. Rob French is the PhD student conducting the project under the supervision of Dr Jayson Semmens and Dr Jeremy Lyle.

What is the purpose of the research and how will it affect you?
Catch and release fishing is used across Australia as a conservation measure for many recreational fisheries. In this regard the effectiveness of catch and release fishing depends on released animals surviving the capture and release process. Physical damage, stress and subsequent survival can be attributed largely to the practices and gears employed by fishers.

This survey will fulfil the third element of a broader study; the other elements involve satellite tagging of makos to assess survival and an examination of stress physiology related to capture and subsequent survival. The questionnaire aims to classify various groups of recreational fishers based on their abilities, experience and motivations for fishing sharks. These groups will then be examined by their gear use, fishing behaviour and attitudes towards fisheries management.

This type of research is important as the recreational fishing community comprises the largest stakeholder in the context of this resource. It is important for the needs of recreational fishers to be met whilst maintaining a sustainable fishery, and this study hopes to identify these needs alongside features of the fishery that may need adjusting such as the use of some gears.

If I choose to participate, what should I do?
If you are reading this cover letter it is likely that you have either acquired the survey through your local game fishing club, or you have decided to find the survey online. Participation is completely voluntary and completely anonymous and once submitted there is no way you may be identified by your submission. If you do choose to complete this questionnaire please take the time to answer each of the questions as accurately as you can. The questionnaire should take around 25 minutes to complete.

How can I enter the draw to win?
Simply fill out the entry form and submit it with your completed questionnaire. The entry forms will be separated from each completed questionnaire so that your answers to the survey remain anonymous. A winner will be chosen by random lottery from all respondents that submitted completed surveys. First prize is a **Shimano Tyrnos 2 speed 50lrs** valued at $400.

How private is the information I give?
Each questionnaire form is completely anonymous and cannot be identified with any single respondent. For this same reason, competition entry forms are separated from survey forms once the survey is verified as complete. Survey responses will be reported in aggregated form, therefore, you cannot be identified as a participant and the data collected will not be made available for marketing or promotional purposes.

Who can I contact if I have questions?
For any concerns about the questionnaire, or the project in general you may contact Rob French via the details below.

Am I able to find out the results of the mako fishing study?
Once completed, the results of this study will be published as part of Rob French's PhD thesis, comprising a peer reviewed article in a social sciences journal. You may also obtain a summary of the results by emailing Rob French at the address below.

How long do I have to participate?
The survey will remain open to responses until September 1st 2014.

Thank you kindly for your time!

Sincerely,

Rob French
PhD Candidate

IMAS, University of Tasmania
Private Bag 49, Hobart
Tasmania, 7007

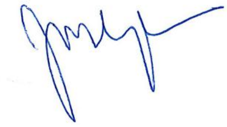
Ph: (03) 6227 7266
Robert.French@utas.edu.au

Jayson Semmens
Primary Supervisor

IMAS, University of Tasmania
Private Bag 49, Hobart
Tasmania, 7007

Ph: (03) 6227 7275
Jayson.Semmens@utas.edu.au

Jeremy Lyle
Co-Supervisor



IMAS, University of Tasmania
Private Bag 49, Hobart
Tasmania, 7007

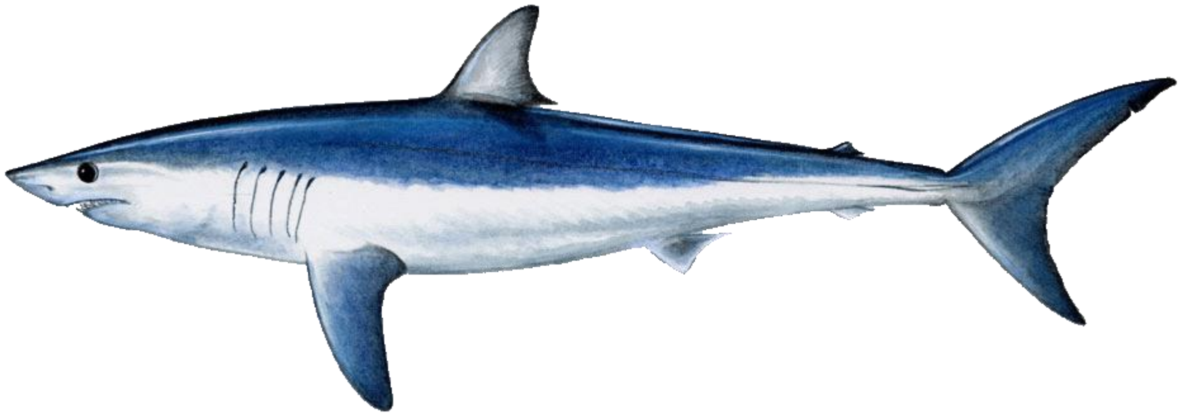
Ph : (03) 6227 7255
Jeremy.Lyle@utas.edu.au

This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 7479 or email: human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H0013984.

Appendix III
Shark Fishing Questionnaire

Recreational Mako Fishing Survey

This survey aims to identify the different groups of anglers that fish for mako sharks in south-eastern Australia and hopes to discover the attitudes and motivations behind their fishing behaviours and practices.



Conducted by the Institute for Marine and Antarctic Studies

University of Tasmania

Please fill and return the following survey using the prepaid envelope provided. If you would prefer to fill out this survey online, the questionnaire can be found at:
https://www.surveymonkey.com/s/makosurvey

All responses to this survey are completely anonymous.

Thank you for taking the time to help our fishery.

Section A: Fishing Experience

A1. How many years of experience have you had fishing? ☐

A2. During the last 12 months, how many days have you fished salt water, whether you caught anything or not? ☐

A3. During the last 12 months, how many days did you spend fishing for mako sharks, whether you caught any or not (if none go to B1, otherwise continue to next question)? ☐

A4. In the last 12 months, how many mako sharks did you personally catch, whether you kept or released them (if none go to B1, otherwise continue to next question)? ☐

A5. In the last 12 months, how many of the mako sharks that you caught did you release? ☐

Section B: Specialisation

B1. Compared to other types of fishing, would you say that mako shark fishing is *(choose one)**:***

☐ The only type of fishing you do.

☐ The most important type of fishing you do.

☐ The second most important type of fishing you do.

☐ One of many types of fishing you do.

B2. Compared to other outdoor activities that you participate in, would you say fishing is *(choose one)**:***

☐ The only outdoor activity you participate in

☐ Your most important outdoor activity

☐ Your second most important outdoor activity

☐ One of many activities you participate in.

B3. Compared to other game fishers how do you rate your own game fishing abilities when targeting mako sharks *(choose one)**?***

Much less skilled	*Less skilled*	*Equally skilled*	*More skilled*	*Much more skilled*
☐	☐	☐	☐	☐

B4. How many subscriptions do you currently have for fishing-related magazines? ☐

B5. Are you currently a member of a fishing club or association?

Yes ☐ ***If so, which one/s?*** *No* ☐

……

……

B6. Over the past 12 months, in which state did you fish for makos the most? ☐

B7. In which state have you spent the most time fishing for makos over your entire fishing career? ☐

B8. What month(s) do you usually (mostly) fish for mako sharks (*Cross all boxes that apply****)?***

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tas												
Vic												
NSW												
SA												

B9. Below is a list of reasons that explain the interest in fishing for makos, please rate the level of importance of each of these to your own fishing experience.

	Very Important	*Important*	*Moderately Important*	*Slightly Important*	*Not at all Important*
The challenge of catching a mako	☐	☐	☐	☐	☐
The large size of makos compared to other species	☐	☐	☐	☐	☐
The makos fighting qualities compared to other species.	☐	☐	☐	☐	☐
The thrill of seeing a mako jump	☐	☐	☐	☐	☐
The high quality flesh of mako for eating	☐	☐	☐	☐	☐
The satisfaction gained from weighing in a large shark	☐	☐	☐	☐	☐
The chance to interact with amazing animals in their natural environment	☐	☐	☐	☐	☐
They are the only game fishing species to target at certain times of the year	☐	☐	☐	☐	☐

B10. The following is a list of statements about <u>ALL OF THE KINDS OF FISHING THAT YOU DO</u>. Please tick a box that indicates your personal level of agreement with each statement:

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
The more fish I catch the happier I am	☐	☐	☐	☐	☐
I usually eat the fish I catch	☐	☐	☐	☐	☐
I would rather catch one big fish than many small fish	☐	☐	☐	☐	☐
I'm just as happy if I don't catch a fish	☐	☐	☐	☐	☐
I'm just as happy if I release the fish I catch	☐	☐	☐	☐	☐
Within legal limits, I prefer to keep all the fish I catch	☐	☐	☐	☐	☐
I'm happiest when I catch a challenging fish	☐	☐	☐	☐	☐
I like to fish where I know I am most likely to catch a trophy-sized fish	☐	☐	☐	☐	☐
I'm not satisfied with a fishing trip unless I catch at least something.	☐	☐	☐	☐	☐

B11. The following is a list of statements about the <u>MAKO FISHING YOU DO</u>. Please tick a box that indicates your personal level of agreement with each statement:

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
The more mako sharks I catch the happier I am	☐	☐	☐	☐	☐
I usually eat the mako sharks I catch	☐	☐	☐	☐	☐
I would rather catch one big mako than several small makos	☐	☐	☐	☐	☐
I'm just as happy if I don't catch a mako	☐	☐	☐	☐	☐
I'm just as happy if I release the mako shark I catch	☐	☐	☐	☐	☐
Within legal catch limits, I prefer to keep all the makos I catch	☐	☐	☐	☐	☐
I'm happiest when I catch a challenging mako shark	☐	☐	☐	☐	☐
I like to fish where I know I will most likely catch a trophy-sized mako	☐	☐	☐	☐	☐
I'm not satisfied with a mako fishing trip unless I catch at least one mako.	☐	☐	☐	☐	☐

Section C: Catch and release versus harvest fishing

C1. Of the following statements, please indicate which best describes your fishing method:

☐ I release all of the mako sharks I catch.

☐ I mainly practise voluntary catch and release fishing, but will retain the occasional mako.

☐ I practise voluntary catch and release and harvest fishing equally for mako sharks.

☐ I mainly keep makos, but will voluntarily practise catch and release on occasion.

☐ I never release a mako shark unless I have to.

C2. Below is a list of reasons people may release mako sharks. Please rate each statement based on your personal motivations for releasing sharks.

I release sharks I could have legally kept because …

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N/A*
I don't like to eat mako shark	☐	☐	☐	☐	☐	☐
I have already caught what I plan to eat	☐	☐	☐	☐	☐	☐
I have an interest in conservation fishing	☐	☐	☐	☐	☐	☐
I enjoy the sport of catch and release fishing	☐	☐	☐	☐	☐	☐
I have reached my bag/possession limit	☐	☐	☐	☐	☐	☐
I am trying to win a tag and release based competition	☐	☐	☐	☐	☐	☐

C3. Which of the following statements best describes your personal fishing preferences and why (choose one)?

☐ I prefer to keep all of the mako sharks I catch

☐ I prefer not to keep small mako sharks

☐ I prefer not to keep large mako sharks

☐ I prefer not to keep any mako sharks I catch

Because: ……

……

……

C4. Below is a list of reasons people may keep mako sharks. Please rate each statement based on your personal motivations for keeping sharks.

I will keep a mako because …

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*N/A*
If I believe the fish won't survive release	☐	☐	☐	☐	☐	☐
If I am fishing for a trophy-sized shark	☐	☐	☐	☐	☐	☐
If I am trying to win a weight based fishing competition	☐	☐	☐	☐	☐	☐
If I am fishing for food	☐	☐	☐	☐	☐	☐
Whenever it is legal to do so	☐	☐	☐	☐	☐	☐
Because I don't catch many mako sharks in a year	☐	☐	☐	☐	☐	☐

C5. Compared to when you first started fishing makos, has more experience prompted you to:

☐ Release more makos than you did previously

☐ Keep and/or release just as many makos as you always did

☐ Keep more makos now than when you started fishing

Section D: Gear Use

The following section aims to explore people's opinions on certain types of gear, and discover whether or not people change the gear they are using based on the size of the shark and what they are planning to do with it.

Figure 1: Standard J hook (Left) next to a circle hook (right).

Figure 2: A non-offset Circle hook (left) is characterised by the tip of the hook being in line with the shank. An offset circle hook (right) features the tip of the hook being bent away from the line of the shank.

D1. What hook do you most commonly use when:

	Circle Hook	*J Hook*	*Hook Size (if known)*
Catching and releasing a small shark	☐	☐	…………
Catching and releasing a large shark	☐	☐	…………
Keeping a small shark	☐	☐	…………
Keeping a large shark	☐	☐	…………

D2. Please rate your level of agreement with the following statements in relation to the use of circle hooks:

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*Unsure /Don't know*
Using circle hooks, rather than J hooks, increases the likelihood of a shark surviving once it is released.	☐	☐	☐	☐	☐	☐
Using circle hooks decreases the likelihood of catching a shark.	☐	☐	☐	☐	☐	☐
Use of circle hooks decreases foul hooking in sharks, including gut-hooks	☐	☐	☐	☐	☐	☐
Using circle hooks, rather than J hooks, reduces the chance of dropping a mako shark once it is hooked.	☐	☐	☐	☐	☐	☐
Circle hooks cause less damage to the shark compared to J hooks	☐	☐	☐	☐	☐	☐
Offset circle hooks are just as effective as non-offset circle hooks at reducing foul hooking.	☐	☐	☐	☐	☐	☐
Using circle hooks decreases catch rates	☐	☐	☐	☐	☐	☐
Using circle hooks makes it harder to hook-up	☐	☐	☐	☐	☐	☐
Using circle hooks decreases hook-up rates	☐	☐	☐	☐	☐	☐
Using circle hooks makes fishing for makos too hard compared to using J hooks.	☐	☐	☐	☐	☐	☐
Using circle hooks makes fishing less enjoyable.	☐	☐	☐	☐	☐	☐
Offsetting circle hooks makes them more effective in hooking-up?	☐	☐	☐	☐	☐	☐
I know how to use circle hooks correctly when fishing for sharks	☐	☐	☐	☐	☐	☐

D3. Please indicate how often you use the following gear when targeting mako sharks for catch and release

If you do not voluntarily release mako sharks please check the following box and continue to the next question: *You do not aim to release mako sharks* ☐

	Always	*Mostly*	*Sometimes*	*Rarely*	*Never*
J hooks (non-offset)	☐	☐	☐	☐	☐
J hooks (offset)	☐	☐	☐	☐	☐
Circle hooks (non-offset)	☐	☐	☐	☐	☐
Circle hooks (offset)	☐	☐	☐	☐	☐
Tail ropes	☐	☐	☐	☐	☐
Tag pole	☐	☐	☐	☐	☐
Gaff	☐	☐	☐	☐	☐

Please indicate how often you use the following gear when targeting mako sharks to retain

If you do not retain mako sharks please check the following box and only fill out catch and release portion of this question: *You do not aim to retain mako sharks* ☐

	Always	*Mostly*	*Sometimes*	*Rarely*	*Never*
J hooks (non-offset)	☐	☐	☐	☐	☐
J hooks (offset)	☐	☐	☐	☐	☐
Circle hooks (non-offset)	☐	☐	☐	☐	☐
Circle hooks (offset)	☐	☐	☐	☐	☐
Tail ropes	☐	☐	☐	☐	☐
Tag pole	☐	☐	☐	☐	☐
Gaff	☐	☐	☐	☐	☐

Section E: Perceptions of sharks and survival

E1. Below is a list of circumstances in which mako sharks are commonly caught. Based on your observations, please rate what you think the likelihood of the sharks survival is, if it were released.

	Almost Certainly Survive	*Likely to Survive*	*50/50 Chance*	*Likely Won't Survive*	*Almost Certainly Won't Survive*	*Unsure/ Don't know*
It is hooked in the gut or throat	☐	☐	☐	☐	☐	☐
It is hooked in the gills	☐	☐	☐	☐	☐	☐
It is bleeding heavily	☐	☐	☐	☐	☐	☐
It has been on the line for a long time	☐	☐	☐	☐	☐	☐
Its tail is wrapped in the trace and it is pulled in backwards	☐	☐	☐	☐	☐	☐
Its body is cut by the trace	☐	☐	☐	☐	☐	☐
It appears non-responsive when bought boat side	☐	☐	☐	☐	☐	☐
It is bought on deck before release	☐	☐	☐	☐	☐	☐
A gaff has been used on the shark to control it	☐	☐	☐	☐	☐	☐

E2. Please rate your level of agreement with the following statements about sharks:

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*Unsure /Don't know*
Outside of game fishing, I believe mako sharks are a danger to people	☐	☐	☐	☐	☐	☐
I only see mako sharks as a source of sport or food	☐	☐	☐	☐	☐	☐
Mako shark populations are able to recover quickly from overfishing	☐	☐	☐	☐	☐	☐
I would not fish for mako sharks if I thought it was not sustainable	☐	☐	☐	☐	☐	☐
I believe my personal fishing activities can have an impact on mako shark stocks	☐	☐	☐	☐	☐	☐
I believe recreational fishing can have an impact on mako shark stocks	☐	☐	☐	☐	☐	☐
I regularly take steps to minimise my impact on shark stocks	☐	☐	☐	☐	☐	☐

E3. In your opinion, do you believe that under current fishing pressures the number of mako sharks in Australian waters is:

- ☐ Decreasing
- ☐ Stable
- ☐ Increasing
- ☐ Unsure

***On what basis have you formed this opinion?*..**

....

....

....

Section F: Environmental attitudes and fisheries management

F1. The following is a list of hypothetical management options for mako sharks in Australian waters. None of these options are currently being formally considered; however, we would like to understand how anglers feel about them. Please indicate your level of agreement with each of the following:

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*Unsure/ Don't Know*
Mako sharks to be strictly catch and release only	☐	☐	☐	☐	☐	☐
Minimum size limits on mako sharks	☐	☐	☐	☐	☐	☐
Maximum size limits on mako sharks	☐	☐	☐	☐	☐	☐
A season possession limit of mako shark per person per year	☐	☐	☐	☐	☐	☐
Closed seasons for fishing mako sharks	☐	☐	☐	☐	☐	☐
Closed areas for fishing mako sharks	☐	☐	☐	☐	☐	☐
Mandatory use of circle hooks to reduce hooking damage in sharks	☐	☐	☐	☐	☐	☐
A limited number of 'permit to keep tags' sold by government each year to ensure that recreational catches are capped	☐	☐	☐	☐	☐	☐

F2. Below is a list of reasons that people may not support fishing regulations for mako sharks.Please rate your personal level of agreement with the following. People may not always support fishing regulations on makos because:

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*Unsure/ Don't Know*
Regulations can be too confusing	☐	☐	☐	☐	☐	☐
Regulations are not needed because populations of mako sharks are not in trouble	☐	☐	☐	☐	☐	☐
Commercial fishing takes too many sharks	☐	☐	☐	☐	☐	☐
Recreational fishing has little effect on the mako shark population	☐	☐	☐	☐	☐	☐
Current levels of catch and release fishing conserves stocks without need for additional regulations	☐	☐	☐	☐	☐	☐
Regulations that force me to release all mako sharks I catch will still result in some of these sharks dying; which would be a waste of the resource	☐	☐	☐	☐	☐	☐
I do not have much trust in management or scientific advice	☐	☐	☐	☐	☐	☐
I do not think enough is currently known about Australian mako populations to form effective regulations.	☐	☐	☐	☐	☐	☐

F3. Please rate the following items in terms of the threat you believe they pose to Australian mako shark stocks.

	Not a threat at all	Slight threat, should be monitored	Somewhat of a threat, current management is effective	Already a threat, needs better management	A serious threat, large changes are needed	Unsure/ Don't Know
Recreational fishing	☐	☐	☐	☐	☐	☐
Commercial fishing bycatch and discards	☐	☐	☐	☐	☐	☐
Loss of prey species	☐	☐	☐	☐	☐	☐
Global warming	☐	☐	☐	☐	☐	☐
Pollution	☐	☐	☐	☐	☐	☐
Lack of appropriate management	☐	☐	☐	☐	☐	☐
Lack of science in management	☐	☐	☐	☐	☐	☐

F4. We are interested in understanding how game fishers view fisheries management in relation to the game fishing regulations in your state. This applies to existing regulations on Shark, Tuna and Marlin where applicable. Please rate your personal level of agreement with the following statements on fisheries management.

	Strongly Agree	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
I believe that fisheries management is needed to keep fisheries sustainable	☐	☐	☐	☐	☐
I think fisheries regulations often 'go too far'	☐	☐	☐	☐	☐
I think regulations in general are not strict enough	☐	☐	☐	☐	☐
I think that fisheries management is often used as a tool of 'the green movement'	☐	☐	☐	☐	☐
Current fisheries regulations are generally based on reliable science	☐	☐	☐	☐	☐
The reasons for regulations are generally communicated in an easy to understand manner	☐	☐	☐	☐	☐
Regulations are not enforced enough	☐	☐	☐	☐	☐
In the face of limited scientific knowledge about fish stocks, management should be precautionary. *For example: If a species is being fished with little scientific knowledge of the stock size, or the stocks ability to recover from fishing; management should regulate fishing to prevent irreversible damage until more is known.*	☐	☐	☐	☐	☐

Section G: Demographic Information

G1. Your age in years ▭

G2. Your gender ☐ Male ☐ Female

G3. Your home address postcode ▭

G4. Your employment status:

☐ Full Time ☐ Casual ☐ Student ☐ Retired

☐ Part Time ☐ Self employed ☐ Unemployed ☐ Pensioner

G5. Your highest level of education completed:

☐ Junior (< 15 years) ☐ HSC/VCE/Matriculation ☐ Diploma

☐ Junior High (> 15 years) ☐ Trade Qualification ☐ Degree